EIGHTH ANNUAL NATIONAL CONFERENCE PROCEEDINGS

AIIE

May 16, 17 & 18, 1957

Hotel Statler, New York City

FRED SCHNEIDER, Proceedings Chairman

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EIGHTH ANNUAL NATIONAL CONFERENCE OF THE AMERICAN INSTITUTE OF INDUSTRIAL ENGINEERS

OFFICE OF THE MAYOR

CITY OF NEW YORK

PROCLAMATION

WHEREAS: THE DETERMINATION, VISION AND IDEALS OF THE INDUSTRIAL ENGINEERING PROFESSION HAVE CONTRIBUTED MIGHTILY TO SOCIAL IMPROVEMENTS AND TECHNICAL ADVANCEMENTS; AND

WHEREAS: THE AMERICAN INSTITUTE OF INDUSTRIAL ENGINEERS HAS DESIGNATED THE PERIOD OF MAY SIXTEENTH THROUGH EIGHTEENTH FOR ITS EIGHTH ANNUAL CONFERENCE AND CONVENTION; AND

WHEREAS: THIS CONFERENCE AND CONVENTION IS BEING HELD AT THE HOTEL STATLER IN THE CITY OF NEW YORK:

NOW, THEREFORE, I, ROBERT F. WAGNER, MAYOR OF THE CITY OF NEW YORK, DO HEREBY PROCLAIM THE WEEK OF MAY TWELFTH, 1957 AS

I N D U S T R I A L E N G I N E E R I N G
W E E K

AND CALL THE ATTENTION OF THE PEOPLE OF THE CITY OF NEW YORK TO THIS PROCLAMATION AND URGE ALL CITIZENS TO BE AWARE OF THE CONTRIBUTION MADE BY THIS PROFESSION.

IN WITNESS WHEREOF I HAVE HEREUNTO SET MY HAND AND CAUSED THE SEAL OF THE CITY OF NEW YORK TO BE AFFIXED THIS 12th DAY OF MAY, 1957

(Signed) Robert F. Wagner
Mayor, The City of New York

FOREWORD

We wish to extend our sincere thanks to each individual author and speaker whose unstinting contribution of their time and effort added so much to the success of this conference. At the same time we also wish to extend our appreciation to them for their excellent cooperation in proofreading and editing of these papers.

We are sure that the high caliber and the lucid explanation of the respective topics will contribute greatly towards making the eighth annual conference a memorable one.

Fred Schneider

Fred Schneider
Chairman Proceedings

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ORGANIZATION, A MANAGEMENT TOOL

M. R. Lohmann
Oklahoma A. and M. College

Introduction:

The satisfaction of most of one's wants is accomplished through cooperative association with others in organization. This appears to have been true throughout history for the difficulties man encounters in coping with his environment to satisfy his needs for the bare essentials of food, clothing, and shelter are so great that it does not seem possible that a human being can long survive alone. Certainly, the survival of the race is dependent on the cooperative organization of the family.

Today, our society is infinitely more complex than that of our forefathers and we are interdependent for the satisfaction of practically all of our wants. Essentially, one's whole life is spent within the scope of organized effort, in such organizations as the family, club, church, and government, as well as the industrial or business enterprise in which one earns his livelihood. Everyone is a member of a large number of organizations. It is through these organizations that we obtain most of life's satisfactions. Organizations are basic units of any society and the means by which the society survives and prospers.

The Effectiveness of Organization is Dependent on the Skill of Managers:

The effectiveness of organization in satisfying one's needs or wants is dependent upon the efficiency by which the contributors to the organization are able to coordinate their activities. The efficiency of coordination is largely dependent upon the adequacy of managers and their skill in managing. Therefore, all of us in most all aspects of our lives are dependent upon this most vital activity, managing. It is a complex activity which may be more difficult to skillfully perform than it is to define and describe, and it is indeed very difficult to define and describe. The failure of organized effort is common and success in maintaining an organization for even a short span of fifty years is comparatively rare. Business failures commonly occur at the rate of 150 per week. Divorces, which are failures of the family organization, average over 7,000 per week.

The need for greater skill in managing has seemingly increased in some ratio, probably exponential, as the number, size, and scope of organizations has increased. The managerial skill possessed by our forefathers which was adequate in their time would probably be inadequate in ours. The very complexity of our society, based as it is on a rapidly developing science, has encouraged if not demanded specialization of efforts by its members. Specialization of effort is so prevalent that extremely few, if any, are able to be self-sufficient in any of the prime physical necessities of life--food, clothing, and shelter. It is surprising that the activity of managing which is so vital to the well-being and probably the survival of our civilization has, until very recently, received so little critical attention and study. For centuries it appears that it was believed that the skill of management was somehow derived from the ownership of land or other tools of production. This belief is not entirely dead. Hereditary managerial positions still exist, not only in certain forms of government, but in many business and industrial enterprises.

The ability to cooperate on an international scale through world government or a world organization is dependent not so much on the ability to frame a scheme of organization with positions, titles, officers, and a constitution or charter, as upon managerial skills necessary to enlist cooperation of those that are essential to the world organization, and to coordinate and control the actions of the participants. It appears doubtful that there is either sufficient knowledge of the management activity or managers with requisite skills to insure the survivorship of so vast an organization.

The success of civic clubs in attaining fellowship and civic improvement is largely dependent on those who are charged with the management function and their ability to obtain the necessary cooperation from the members and their skill in coordinating the member's activities. Even the stability and happiness of the family is largely dependent upon the skill of the parents as managers of their children. The rearing of children is not commonly thought of as a managing function, but any father or mother will attest to the difficulty and complexity of the task. The activity of managing is pervasive and being so, it has somehow tended, until very recently, to escape our attention and study, particularly in areas outside of the industrial enterprise.

Our attention has for nearly two hundred years since the industrial revolution been focused on the machine as the means of increasing our productivity and our standard of living. Now we find, especially as we attempt to introduce technology into the backward areas of the world, that skill in organization is at least equally responsible for contributing to the United States' great productivity. It has been estimated that one-half of the annual gain in productivity comes from better organization and one-half from better technology. Despite the marvelous achievements in science the past years, I predict that the twentieth century will not be remembered as much for the growth in science and technology as for the growth in size and scope of organizations.

Thus, today's managers, particularly of our industrial and political organizations, must possess considerable skill in organizing the activities of many men. To properly design an organization, it is necessary to first understand what constitutes an organization and how it functions. The plan of presentation of this paper is to first define and describe several kinds of organizations and the activity of managing in a way useful to understanding their relationship. To plan the growth of an organization, it is helpful to understand the method of growth and the limiting factor of growth, which is managerial communication. And lastly there are some comments on innovations of bases of specialization as a means of increasing coordination. The plan is to present a conceptual scheme useful for thinking about and solving your unique organizational problems. It is not the purpose to enumerate a set of procedures, illustrated by a few examples as the answers to your problems.

Definitions:

The language of organization and management lacks much in being precise. The term organization commonly denotes an association of some kind. The General Electric Company, the Center City Rotary Club, and the Jones family are commonly considered to be organizations by virtue of being associations of people. But, associations of machine parts, ideas, insects, and animals, and of course, biological parts, also are something considered to be organizations. In this paper, the meaning of the

words unit organization will be used to designate an association of acts of people. This meaning corresponds to Barnard's definition of formal organization which may be stated as follows: (1)

A unit organization is a system of consciously coordinated activities of two or more persons.

When two or more unit organizations are in a system of cooperation, it will be called an organization and is defined as follows:

An organization is a coordinated system of unit organizations.

It is apparent that the matrix of society is a countless number of unit organizations intertwined and intermingled in a confusing and interlocking pattern. One system of cooperative activities is part of a larger system and this is part of a still larger system. For example, one contributes activities to the following governments: precinct, ward, city, township, county, state, and nation. Each is a system of activities within another system. This mass of unit organizations is not independent, but interdependent. The functioning of one is dependent upon, in some degree, the functioning of all other unit organizations. This is apparent in the Standard Oil Company (New Jersey) which is wholly dependent upon its subsidiary companies, and each subsidiary company is dependent upon its component divisions such as production, exploration, and refining. Each division is dependent upon departments and so on and on through the whole structure. The knowledge of interdependence of unit organizations, and particularly the character and strength of the relationship is of great value to managers.

The usual methods of abstracting some characteristics of organizations from all the organizations composing society is not useful for our purpose. Organizations have been classified by type of ownership (single proprietor, partnership, corporation), by product (oil, steel), by number of employees, by assets, by value of products produced and many other criteria.

Our purpose is to classify unit organizations in terms of the means by which the activities contributed are coordinated. The activities of persons in unit organizations may be coordinated in two ways. A contributor, by perceiving the activities of other contributors, may, on the basis of this perception or communication, control his activities so that they are coordinated. This type of coordination is called self-coordination. Most of our daily activities within organizations are primarily self-coordinated.

The second method of coordinating activities is by a "recognized" coordinator or manager. The contributors of the activities recognize someone as being the coordinator and accept his communications or orders as controlling or governing the activities they contribute. Managerially coordinated activities are a small but extremely important part of our total daily physical acts.

Kinds of Unit Organizations Illustrated:

For purposes of analysis and understanding of everyday organizations, it is useful to classify all unit organizations into either formal unit organizations or informal unit organizations. These will be illustrated by the example below and then each will be defined.

Suppose that three blindfolded men are seated around a table at intervals of about 120° as in Figure 1. Each person is asked to grasp one end of a cord whose other end is attached to a plummet resting near the center of the table and near an open container. Consider that the three blindfolded men and a fourth person, termed a coordinator (manager), not blindfolded and standing near the table, are to move the plummet into the container. This resultant can be accomplished by the three blindfolded men if they can coordinate their actions so that the tension placed on each cord in successive moments is such that the plummet is transported to a position over the container and then lowered.

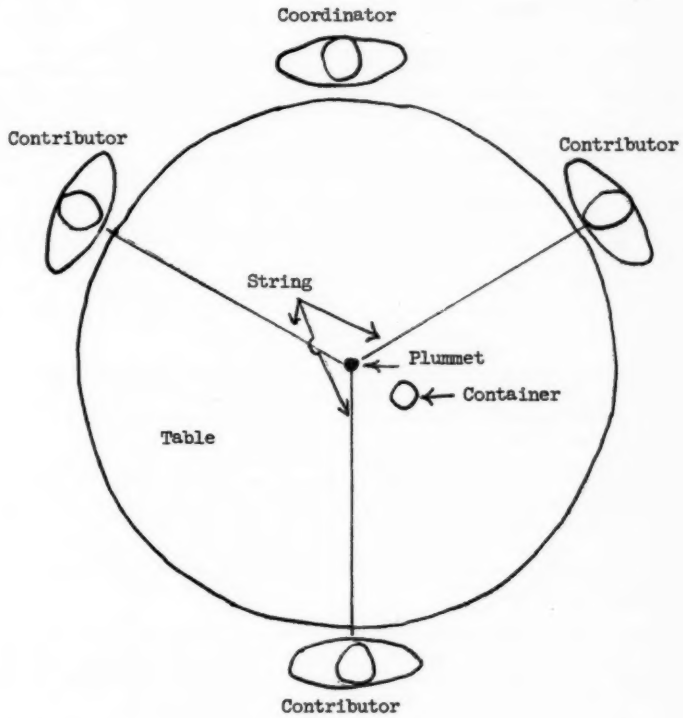

Figure 1: - Blindfolded contributors of activities constituting a formal unit organization.

First assume that the coordinator is "recognized" by the blindfolded men; that is to say, they will accept the coordinator's directions as controlling their actions. Next, assume that the coordinator observes the situation in successive moments and communicates directions that enable the blindfolded men to coordinate their acts to move the plummet into the container. In this illustration, there is a coordinator whose directions are acted upon by contributors. The coordinator is stimulated by moment to moment observations of the situation and translates the received sight stimuli into communication sound stimuli which are received by the blindfolded men and which control their actions sufficiently well to accomplish the task. The system of coordinated acts of the four men in the above example embraces the essentials of formal unit organization.

If the three men holding the cords are not blindfolded, it is likely that a simple directive similar to "please place the plummet into the container" will be sufficient for them to coordinate the forces applied to the cords for accomplishment of the task.

In this case, the moment to moment positions of the plummet in relation to the container directly stimulate each contributor to supply acts appropriate to the joint effort and a recognized coordinator is unnecessary. In the latter case, where each contributor is guided alone by his own observations of the situation, the system of coordinated acts of the three men constitutes an informal unit organization.

Formal Unit Organization:

A formal unit organization is a unit organization in which coordination of the acts of operative contributors is achieved through communication of a recognized coordinative contributor. The formal unit organization is a system of personal acts in continuous coordination. The continuous coordination is achieved, at least in part, by means of communication of a recognized coordinative contributor.

The adjective formal in the term formal unit organization is suggested by the implied selection of a common coordinative contributor by the operative contributors, and their acceptance of his communications as governing their actions. Also in business, industrial, civic, and social associations some supervisory personnel are more or less formally designated as such, and these supervisory personnel are usually found in the roll of coordinative contributors in formal unit organizations more frequently than other contributors.

Activities of a formal unit organization are referred to as being manager-coordinated.

There are countless situations in which close coordination of two or more persons is needed where it is advantageous to have one contributor specialize in the activities of observation and communication of directions. To the extent that complete directives are given by one contributor to enable other contributors to coordinate their acts, the latter are relieved of the necessity of observing and perceiving the acts each should supply. Also, a coordinative contributor's communication may relieve operative contributors, in part, of considering the cooperative prospective resultant and of recognizing the incentives that they may receive from achievement of the prospective resultant. This often greatly facilitates cooperative effort.

In the example pictured in Figure 1 in which the operative contributors were blindfolded, it is apparent that they were almost entirely dependent upon the coordinative contributor's communication for maintaining continuous coordination of their acts. The coordinative contributor's acts are as much a part of the organization as are acts of operative contributors although the former do not directly enter into the achievement of the resultant as has been explained previously.

There are, of course, many situations in which the operative contributors depend partially upon their own observations and partially upon that of a coordinative contributor to maintain coordination. The same is true in regard to knowing the resultant of cooperation and to recognizing incentives.

Informal Unit Organization:

An informal unit organization is a unit organization in which coordination of the acts of operative contributors is achieved through perception of operative contributors.

An informal unit organization is a system of personal acts in continuous coordination. The continuous coordination is achieved by means of each operative contributor observing the environment, including other contributors, and on the basis of his observation, supplying appropriate acts. Informal unit organizations do not involve either observations or communications of coordinative contributors. Activities of informal organizations are referred to as being self-coordinated.

When the blindfolds had been removed in the example illustrated in Figure 1, the three men were able to coordinate their acts to move the plummet into the container solely on the basis of the independent observations and motivation of each contributor. In other words, the activities of each contributor were self-coordinated.

Observation of organized activity leads to the conclusion that most of the accomplishment of organizations is the resultant of self-coordinated effort. Employers are constantly on the look-out for employees who do not have to be told everything. An objective of the development of proficiency in a person through instruction and practice is often to enable him to coordinate his activities with others on the basis of his own initiative. In this connection, consider the coordination of football players who receive no direction after the ball is snapped. Similarly, many, if not most of the directions given in industry consist largely of telling individuals or teams of workers what objectives they are to attain; the workers are depended upon to self-coordinate their actions as required to achieve the assigned objective.

Essentials of a Unit Organization:

From the definition of a unit organization as a system of consciously coordinated activities or forces of two or more persons, the minimum conditions for the existence of a unit organization may be inferred. Coordination of activities is meaningless unless they are coordinated to attain an end. People will not contribute activities toward the achievement of ends which do not result in a net benefit to them. It follows that a prospective resultant of cooperation must be known and acceptable to the contributors before they will cooperate. The resultant may not be achieved, but at the time of cooperation, a resultant must be contemplated and its net benefits must be anticipated by the contributors. In organizations beyond the very simplest and certainly in all industries, there is a

whole hierarchy of resultants of coordinated activities. For example, men coordinate their activities so that a ditch is dug; a ditch is dug to pour a foundation; a foundation is poured to build a factory; and a factory is built to produce automobiles. Certainly the first product of cooperation, the ditch in the example above, must be known by the diggers even though they may question its desirability, so that they may effectively coordinate their efforts. Thus, one of the essentials of a unit organization is a known and agreed upon prospective resultant of cooperation.

The activities that are consciously coordinated in a unit organization must be contributed by people. Though a unit organization is impersonal, persons must be induced to contribute needed physical acts to it. Inducements in the form of incentives of some kind must always be present. Some incentives are tangible and material, others intangible; some are positive, others are negative or coercive. The incentives to contribute may be in the form of benefits, or they may reduce present burdens. Incentives in one form or another must be available in sufficient quantities to induce a potential contributor to perform the needed physical acts. Thus, a second essential of a unit organization is a recognition of incentives by contributors that induce them to contribute needed acts.

The coordination of activities is accomplished when the separate physical acts are contributed at the "right" time, place, and manner. The contributors may perceive needed appropriate acts through any of their senses, but usually by means of hearing oral communications, by seeing written communications, or by hearing or seeing the activities of other contributors and environmental factors. In any case, information relating to the kind of activity and the time, place, and manner of delivery must reach the potential contributor so that he will act appropriately to achieve the contemplated resultant.

The third essential of a unit organization is the perception of the acts needed to achieve the prospective resultant of cooperation. Summary of Essentials of a Unit Organization:

A unit organization comes into being and endures when two or more persons:

1. Know and agree upon a prospective resultant of cooperation.
2. Recognize incentives that induce the contribution of activities.
3. Perceive the acts needed to achieve the prospective resultant.

The Activity of Managing:

Managing is a physical activity, a part of the system of activities of a unit organization. It is a communicative activity whose purpose is to initiate or maintain the system of coordinated activities. The activity of managing consists of communicating to aid operative contributors to know and agree upon a prospective resultant of cooperation, to recognize incentives that induce them to contribute acts, and to perceive the acts needed to achieve the prospective resultant. A manager communicates to the contributors whose activities he coordinates. He communicates about the resultant of the activities of these contributors and the relationship of the resultant to the resultants of other unit organizations, particularly within the industrial enterprise. The manager communicates about the incentives, their source, and their ability to satisfy contributors, and he communicates about the physical, biological, and social environment that aids the contributor to perceive the kind of activities needed at the right time, place, and manner.

The activity of managing does not directly become a part of the resultant of cooperation; it is an activity that serves much as a catalyst serves two chemicals. It stimulates the reaction without necessarily becoming a part of the product. A manager may be compared to the driver of a car. He only guides or steers the automobile, he doesn't provide the power. Managing activities are always directed toward the operative contributors of activities, never directly toward the resultant of the activities.

Management is defined as the activity of communicating to contributors to aid them in agreeing upon a resultant, recognizing incentives, and perceiving the acts needed to achieve purposeful coordinations of their activities.

Methods of Growth of Organizations:

If one is to plan or design an organizational structure, prepare organization charts, and consider such problems as the span of control, the assignment of duties and responsibilities, and the relationships of the various individuals and unit organizations in an industrial organization, knowledge of the methods of growth seems essential.

There is obviously a limit to the number of physical acts of contributors that can be effectively coordinated by a manager. This is a more exact way of stating that there are practical limitations to the size of unit organizations. Organizational growth of a substantial nature consists therefore of adding unit organizations to a complex.

Organizations grow in much the same way as biological organisms. The human body grows from an original single cell to which other cells are rapidly added throughout the early growth period until the body reaches maturity; and then more slowly at a rate approximately equal to wastage in order to maintain a stable living organism. Every cell in the human body is in a greater or lesser degree dependent upon every other cell for its survival. The failure of a single cell, if not replaced, may cause the failure or death of other cells and eventually the death of the organism. In much the same way, a complex of formal unit organizations grows from a single unit organization, and the dependency of every unit organization upon the other unit organizations in the complex is similar to one cell's dependency upon the other body cells in the organism.

A cell may fail or die because of a failure of any of its constituent parts. A unit organization may fail because of the failure or the withholding of activity that is vital to achieving the prospective resultant. In the same way that a healthy, functioning cell tends to grow, so a unit organization in which there is a surplus of satisfaction for contributors also tends to grow. But there are limits to size of cells and unit organizations, and continued growth of each may lead to subdivision. The subdivided cells or unit organizations may then grow, be subdivided, and grow again. This is the method of growth of organisms and organizations.

Organizations generally, and business and industrial organizations particularly, have a strong tendency for growth. From a single formal unit organization, great complexes of thousands of unit organizations have grown. But before each of these thousands of unit organizations came into being, the three essentials of organization had to be present simultaneously. For each formal unit organization or informal organization to be active, the essentials must be present continuously.

By a process of subdivision, additional formal unit organizations are formed and then integrated by communication into the complex of unit organizations. The ultimate structure of the complex of unit organizations is a result of a manager's attempts to so adapt an organization's structure to cope effectively with the environment. As the physical and social environments that hinder effective cooperation are different, in large or small degree, for every organization, it is not surprising that differences in structure are common even for industrial organizations producing the same product.

Contributors are added to existing formal unit organizations until it is believed greater effectiveness may be achieved by an additional formal unit organization. Workmen are added to a foreman's formal unit organization until it is believed that efficiency would be improved by forming a new formal unit organization under a second foreman.

Theoretically, at least, a formal unit organization might consist of the contributions of thousands of men under the direction of a single coordinator. In fact, in special situations such as a public lecture or a political rally, unit organizations may be extremely large. But in the usual industrial situations, it seems impossible to attain adequate coordination if there is only one manager with thousands of operative contributors in a single unit organization. Industrial organizations, the government and the Army, to name only a few, generally are characterized by a majority of formal unit organizations with fewer than twenty contributors.

As the size of the unit organization increases, the problem of coordinating the physical acts of large numbers of contributors increases. As the number of unit organizations increases, the problem of coordinating the resultants of units increases. The recognition of these two problems has led to the formulation of two conflicting principles of management, namely, that effectiveness is increased by limiting the number of subordinates reporting to one superior, and secondly that effectiveness is increased by limiting the number of organizational levels. Clearly, both statements cannot simultaneously apply to a particular situation. Obviously there is some optimum combination of unit size and number of units which will result in greatest effectiveness. Thus neither "principle" can be applied alone and indiscriminately.

Organizational Analysis and Planning:

The efficiency of a unit organization and the effectiveness of an organization are always limited by the necessity for, and the adequacy of a manager's communications to subordinates about the essentials of organization. Thus, design of an organizational structure always has the objective of (1) reducing the necessity for communication for a given amount of coordination, or (2) improving the coordination for a given amount of communication.

When one studies an organization for the purpose of improving the organizational structure, one actually studies the flow of information necessary to coordinate the activities. The final grouping of activities into a job and the placement of the job in the organizational hierarchy is done on the basis of minimizing the necessity for communications or improving coordination for a given amount of communication.

Organizational study begins with a study of the activities that are required to produce a resultant. All activities must be performed at a

time, in a place, by a person, or something, in a definite manner. If the critical factor for effective coordination is time, then time is the principal basis of specialization, and all other bases of specialization are subordinated to it. The five bases of specialization as they apply to activities of individuals in unit organizations and to activities of unit organizations in a complex or unit organizations are:

(1) the time the activity is contributed
(2) the place where the activity is contributed
(3) the persons who contribute the activity
(4) the things in relation to which the activity is contributed
(5) the manner or method by which the activity is contributed

All acts performed in formal unit organizations in a complex of formal unit organizations are specialized in accordance with the above five bases, but one of the bases is usually dominant. When the number of activities of a formal unit organization becomes too large for effective coordination, some of the activities may be classified on one of the bases of specialization and be coordinated in a new formal unit organization. This classification is done by managers who select from the total activities those activities which are similarly specialized. The resultant achieved by these specialized activities is combined with the resultants achieved in other units of specialized activities to form the product of the organization.

As each new formal unit organization is formed by division of a formal unit organization, the resultant of the latter formal unit organization is divided and the activities of the new formal unit organization are specialized according to principally one of the five bases of specialization; time, place, persons, things, and manner. The basis of specialization must meet the criterion of efficiency. In many situations, it is extremely difficult to select the most effective mode of specialization. For example, when engineers or other technical specialists are geographically separated, should the distance be ignored and all engineers organized into a formal unit organization which would be a specialization by persons, or should the engineers be included in the local formal unit organization which would be specialization by place?

Because physical acts are the contributions of persons, men have similar bases of specialization. The specialization of the formal unit organization is dependent upon the availability of persons of that specialization. Although it may not be difficult to obtain unskilled and semi-skilled labor for the "swing" shift, it may be impossible to obtain highly skilled craftsmen such as tool and die makers to work those less desirable hours. The selection of the basis of specialization of activities for the new formal unit is thus always dependent on the estimation of the availability of persons of that specialization. The degree of coordination attained between unit organizations is dependent upon how well the contributors are able to specialize their activities. All the coordinative techniques such as motion study, time study, production planning and control, and plant layout are attempts to attain a high degree of specialization of activities and, therefore, a high degree of efficiency.

The physical and social environment affects the specialization selected. In organizations such as oil producing companies or highly perishable food processing and canning companies, the obstacles to communication and coordination imposed by wide geographical separation greatly influence the selection of highly decentralized organization, which is

specialization by place. The practice of segregating the races in some areas is a recognition of the social environment and is a specialization by persons.

The resultant of the complex of unit organizations is achieved by accomplishing the resultant of each unit at the right time, place, and manner. It is important for managers to always bear in mind that the Ford Motor Company does not produce automobiles; unit organizations of the complex of unit organizations which is called the Ford Motor Company accomplished specified resultants in the right time, place, and manner, and the combination of the resultants of all the unit organizations becomes the Ford automobile. This point is stressed, for the skill of organizing lies in the inventing of new patterns for breaking down a resultant of a complex into sub-resultants to be achieved by specialized units. A great contribution of Henry Ford was the invention of the mass assembly line which was an innovation of organization based on unit organizations highly specialized in respect to time.

Growth of Managerial and Staff Organization:

The process of specialization is obviously not limited to activities that contribute directly to the accomplishment of a specific material resultant. In fact, the concentration of activities of communication for coordination in a single person is what distinguishes a formal from an informal unit organization, and is a specialization. A manager is a specialist in communication. As unit organizations are added to a complex, the scope of the communication activities needed to coordinate the physical acts of larger groups of men, increases, probably at some exponential rate. A pyramid of unit organizations is formed, and the manager at the apex as well as managers at other levels are not always in direct contact with those whose efforts they are trying to coordinate. To a large extent, they depend upon the stimuli of written and oral reports.

Due to the need for securing proper coordination at the work level of organization when the number of unit organizations is large, there is a specialization of the managerial organization. A manager cannot perform all the activities required to secure the coordination of those he supervises directly and indirectly because of his limitations. For this reason a specialized formal unit organization called a staff may be formed to perform certain activities for the manager. The development of the staff function and the line and staff organization has been the principal organizational change of the past half century. To this innovation of organization can be credited much of the genius of organization that American industrialists are reported to have. Without highly developed staff unit organizations whose function is to aid managers to coordinate the activities of their subordinates, the great industrial organizations could never have come into being. Formal unit organizations engaged in such activities as production planning and control, purchasing, accounting, budgeting and auditing, time study, and many others were developed to gather and present information to managers. From these specialized unit organizations comes a vast number of reports, oral and written, which are stimuli impinging upon managers at all levels. These are relayed in part in the form of orders and reports down to operative personnel at the lowest level of the organizational pyramid. While there is a specialization in the managerial function, these managerial and staff unit organizations have as their basic function the influencing of the operative group toward a system of coordinated activities. Everyone in

the organizational pyramid above the operative group is assisting in bringing stimuli to operators to guide their hands in performing the right acts at the proper time, place, and manner.

It is interesting to note that the number of staff unit organizations in industrial organizations has increased tremendously in the past fifty years and a whole new class of clerical and technical workers has come into being. All indications seem to point to continuing growth in the number of staff unit organizations, particularly those related to techniques. This is an indication that greater over-all productivity is being attained not by adding greater numbers of workers but by a higher degree of coordination from highly specialized unit organizations and workers.

Organization, as a management tool, is not well developed because it is not well understood. Only in the last decade have a few of the largest corporations established departments of even one man whose primary function is to do organizational analysis and planning. Although the management book shelves contain several volumes on organizational analysis and planning, they are primarily case books of practice without a development of theory to justify the practice. Although the pragmatic test of "Does it work?" is good, it is not possible to teach organizational planning until we know "why it works."

Because I am primarily interested in developing an understanding of theory of organization, this paper has omitted the "practical" examples. It is my hope that an understanding of theory by you, the practitioners of organizational planning, will hasten new inventions of specialization, and new inventions will be needed if industry is to continue to grow in size and complexity.

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(1) Barnard, Chester I. The Functions of the Executive, p. 81. Cambridge, Harvard University Press, 1938.

HOW TO RECOGNIZE THE NEED FOR AN INDUSTRIAL ENGINEERING PROGRAM

Harold B. Maynard
Methods Engineering Council

Let's begin by discussing what we mean by the term "industrial engineering program." For many years, industrial engineering was considered to be nearly synonomous with time and motion study and wage incentive application. It was applied largely in the factory. But as time went on, it became evident that the open-minded, analytical approach of the industrial engineer when focused on other areas of a business resulted in the development of improved ways of doing practically all tasks accomplished through human effort. The activities of the industrial engineer have, therefore, broadened tremendously. One has only to read the list of chapter titles in McGraw-Hill's "Industrial Engineering Handbook" to see how wide the interests of the industrial engineer now are and to gain an appreciation of the number of ways in which he can serve his company. Methods improvement, cost reduction, wage incentives, job evaluation and merit rating, production planning and control, plant location, inventory control, product design, management controls, tool and gage design, office methods and standards, quality control, distribution methods, operations research -- this is but a partial list of the activities with which the modern industrial engineer is directly or indirectly concerned.

Industrial engineering today, therefore, may be broadly defined as the engineering approach applied to the improvement of all functions involved in the design, production, and distribution of products or services. An industrial engineering program is a planned way of applying industrial engineering so that the resulting improvements will be obtained in an orderly, economical manner.

With this in mind, we are ready for a question. When does a company need an industrial engineering program? Harlowe Curtis, President of General Motors, suggested the answer. He said "Remember that no strike, no war, no disaster can so completely and irrevocably destroy a man's business or his profits as better methods in the hands of an enlightened competitor." Human experience as recorded on the pages of history has shown that there is always a better method for doing any task waiting to be discovered by those who are driven by dissatisfaction with things as they are.

So, since the chief business of any industrial engineer is methods improvement, it follows that the company that wishes to survive in a competitive economy needs an industrial engineering program. It needs someone continually searching for better ways of doing things, lest it lose its competitive position to a more progressive firm.

Obvious as the need for an industrial engineering program may be to those who understand what it can accomplish, there are many companies that do not have such programs. T. A. Marshall, Jr., Assistant Secretary of the American Society of Mechanical Engineers, writing on the scope of the Industrial Engineering Function in the "Industrial Engineering Handbook" had this to say:

"There are over 300,000 manufacturing concerns in the United States having less than 250 employees. Most of these do not use industrial engineers or industrial engineering techniques. Many of our larger businesses, too, have not yet learned the value of these techniques in aiding successful enterprises."

Here then is a large group of companies that has not yet recognized the need for an industrial engineering program. When we add to this the companies that are making only partial use of the services the industrial engineer has to offer -- those that limit the application to direct labor, for example -- it becomes apparent that in spite of the many brilliant industrial engineering installations that have been made, there is much more to be accomplished than has yet been done.

It is fortunate that the potential for further accomplishment is so great, however. We are faced in America at the present time with three inescapable facts.

1. The total population is growing at an explosive rate.
2. The proportion of productive workers to total population is shrinking.
3. To have more, we must produce more.

In other words, we are facing a situation where if our standard of living is to continue to improve constantly as it has in the past, we must keep on increasing our productivity more and more. And this means not only the productivity of those who produce with their hands, but those who produce with their heads as well.

New materials, new processes, electronic office equipment, continued development of automation will help to increase productivity to be sure. But more important in the aggregate, although less spectacular, is the patient, detailed work that the industrial engineer does as he examines each repetitive job motion by motion; designs easier, quicker, and less fatiguing methods; and establishes management controls by means of measurement. More important in its effect on conserving our limited labor resources are his excursions into the field of indirect labor. By learning how to organize, measure, and control such activities as maintenance work and office functions he is beginning to make major methods improvements and cost reductions there too. Even the specialized management functions such as engineering, sales, cost accounting, and the like are being rendered more effective by the analytical studies of the industrial engineer. The sum of the results of these and the other activities he undertakes contributes importantly to the constant raising of the level of productivity of the successful enterprises in which he works. It is fortunate, as I have said, that there is such a large as yet untouched field for his work available to him. It offers the potential for still further substantial increases in productivity, increases which will be vital to our material well being as we continue to grow in population in the years ahead.

But, this is at present only a potential field. Regardless of what the industrial engineer may think, the companies that make up the potential have not yet recognized what the industrial engineer can do for them. Otherwise they would have added him to the management staff long ago. They have felt that they can get along all right without an in-

dustrial engineering program, that they can be successful without using the industrial engineering approach for the solution of their problems. When the suggestion is made that they could use industrial engineering to advantage, they have all the answers to justify their lack of acceptance from "our work is different" to "we tried it before and it didn't work." How is the industrial engineer going to be able to break down such attitudes and get these companies to give him the opportunity to bring to them the benefits he has to offer? How is he to sell them on the value of his product?

There is no simple pat formula which will give an easy and quick solution to this problem. We are dealing here with human attitudes and understanding. It is not easy to alter attitudes, and it takes time to develop understanding. But it can be done by patient explanation and gradual education whenever the opportunity presents. Whenever the industrial engineer hears a negative comment about the value of his work or the project he is proposing to carry out, he should not regard it as something to discourage him, but rather as an opportunity to gain a convert through constructive discussion.

After all, he is not the first one in the field of industrial engineering to have cold water thrown on his ideas. The pioneers had a rocky road indeed. They were proposing something new and relatively untried. They were misunderstood, rebuffed, even ridiculed time and time again. But they persisted and eventually with the aid of a few progressive managers of their day were able to demonstrate that their ideas were sound. While they were making sound installations of lasting value in the companies where they worked, however, the so-called "efficiency experts" moved in to other companies. By unethical tactics and the misapplication of the basic principles propounded by the pioneers, they confused the recognition of what industrial engineering, properly applied, can do and left for the sound practitioners some difficult obstacles to overcome.

But the pioneers and the first and second generation industrial engineers persisted and gradually built up a body of successful applications which have made it much easier for present day industrial engineers to demonstrate the value of their work. Their efforts can be used to help the manager of any company to recognize the need for an industrial engineering program. And every industrial engineer who regards himself as a professional man has the responsibility of sharing in the task of helping to gain recognition for the value of his work.

There are four ways in which the industrial engineer can contribute. These are:

1. By shaping management attitudes towards industrial engineering.

2. By helping management to understand its role in the industrial engineering program.

3. By working cooperatively and harmoniously with labor on all phases of the industrial engineering activity.

4. By being technically competent personally.

Let's consider each of these in turn. Although time does not permit an exhaustive discussion, we can at least outline some of the more important aspects of each point. Also to avoid the confusion that comes from trying to cover too great an area in too short a time, let's limit our discussion largely to the methods improvement, work measurement, and wage incentive phases of industrial engineering.

Assume, first of all, that an industrial engineer has recognized that a certain company will benefit by the introduction of an industrial engineering program. He approaches the owner or manager of the company with the idea and encounters an attitude of resistance. A definite prejudice against industrial engineering is expressed. Attitudes of this sort, unless emotionally based on a previous unhappy personal experience, are likely to be based on misunderstanding. Often explanation and discussion can clear them up. Although this may not bring immediate change in attitude, it can pave the way for more rational discussions at a later time. The industrial engineer should never pass up the opportunity to improve understanding of the industrial engineering function and what it can do.

Here are some typical expressions of misunderstanding and prejudice and some of the facts that can be used as countermeasures.

1. *Our product is very simple. We have been making it profitably for years. We don't need industrial engineering.*

Satisfaction with a present situation is a dangerous attitude to take. Methods can always be improved. The production methods used to produce simple products most of all lend themselves to constant improvement, at least until the point of full automation is reached. And because they are simple, many people will be able to recognize ways of making improvements.

Then again, conditions themselves are constantly changing. Just because last year or the last ten years were profitable is no sign that next year will be profitable too. Forces beyond the control of the individual company are always at work. Matt Murphy, Editor of Factory Management and Maintenance, in his analysis of what is ahead for manufacturing industry in the year to come predicted:

> "1957 promises to be a big and productive year in terms of volume of business in manufacturing. But it also threatens to be an inflationary year. This means more cost pressure on operating men, and more incentive for all of management to improve manufacturing methods."

No one is in such a strong position that he can safely say that he does not need the methods improvements brought about by industrial engineering.

2. *Our materials vary so we can't have standard methods and time standards.*

This is a favorite in industries where materials -- leather, for example -- are grown rather than manufactured, although it is heard in every other industry as well, including metal working. It is true that materials do vary and the industrial engineer would be unrealistic

if he did not admit it. The variations are limited, however, and the number of different motion patterns the variations cause are usually few and identifiable. Frequency studies will show if standards should be set for each variation, if a single standard based on average or representative conditions will be satisfactory, or if some other treatment will be more practical. The fact that other companies in the same industry use industrial engineering successfully is a prime indication that after careful study a satisfactory solution can be found.

3. *Our quantities are too small.*

There are many successful applications of industrial engineering to tool rooms, maintenance work, and similar non-repetitive activities. Furthermore, it is usual to assume that the larger companies using industrial engineering have highly repetitive work, when actually they have many departments dealing with miscellaneous small quantity work. Industrial engineering techniques have now been developed to the point where they may profitably be applied to the job-shop or specialty manufacturer.

4. *Our productive labor is a small part of our total cost.*

Who says that the industrial engineering approach is limited to productive labor? It is of value wherever there is a problem to be solved. A wholesale drug company has no productive labor, yet it has used industrial engineering to improve the effectiveness of its salesmen, to increase productivity in its purchasing department, and to improve methods and reduce costs in its many warehouses. Industrial engineering is not limited to time and motion study, wage incentives, or plant layout. It is not applicable only in mass production factories. Industrial engineering basically is an open-minded approach to finding better, less costly ways of doing things and then establishing controls so that these ways will be followed reasonably diligently in the future. All types of activity will benefit from industrial engineering study.

5. *The XYZ Company got into hot water with its industrial engineering program and had to throw it out.*

For every XYZ Company there are a hundred ABC Companies who have gotten satisfactory results from industrial engineering. It requires skill to use the procedure properly. When this skill is lacking, difficulties may well result. We do not advocate treating industrial engineering lightly or entrusting its introduction to inexperienced clerks. But properly introduced, installed, and administered, industrial engineering can contribute importantly to the success of any company. It is not just coincidence, that the leading companies in most industries are the most aggressive users of industrial engineering.

6. *But we're too small for anything like that.*

No company is too small to benefit from the industrial engineering approach. Many small companies are unhappy about the situation in which they find themselves today. They complain that unions force them to pay the same wages paid by the big companies. They say that they must meet the price schedules established by their larger competitors.

The result is, they say, that they can no longer operate as profitably as they have in the past.

It is difficult to follow such reasoning. Profits should not be sought from substandard wages or out-of-line high prices. Profits come from sound management and a never-ending search for better methods. Some of the small companies that complain the loudest about big company competition do not have an industrial engineering program. But they can have and, indeed, must have to compete with the companies that use industrial engineers.

A small company cannot afford an elaborate staff of specialists, but neither can it afford to neglect the matter of cost reduction and control if it is to compete with the "bigs." Perhaps a man who devotes only part of his time to industrial engineering activities is all that is economically justified. Or, in the very small company, perhaps appreciation training for the owner-manager in the simpler industrial engineering techniques may be the answer. But in any case, the approach represented by industrial engineering cannot be neglected indefinitely by any company that wishes to prosper and grow.

Not all negative attitudes emanate from those who have never used industrial engineering. Many managers who have used it successfully for years on a portion of their work have difficulty in seeing how the application can be extended. Typical of these attitudes are the following.

7. *We have our direct labor covered, but you can't do anything with the indirect.*

Some of the greatest cost reductions resulting from improved methods, work measurement, and management controls are today being made on indirect labor. The first industrial engineering studies were naturally made on repetitive direct labor operations, because they were the easiest to cover. Success in this area, led to the demand to cover other less repetitive work. Through the constant improvement of their techniques, industrial engineers have reached the point where they can now economically measure practically all forms of human activity including many of the white collar and clerical operations.

8. *We have standards on everything now.*

Many people associate industrial engineering largely with time study and standards. Although this is an important and useful part of his work, the industrial engineer does many other things. We have already mentioned methods improvement a number of times. This is a never-ending task, for the tenet of the industrial engineer "with sufficient study, any method can be improved" applies to all methods including those just recently improved. In addition, the industrial engineer performs himself or importantly influences a number of other manufacturing functions. It is doubtful if any company, no matter how progressive, has as yet realized the full potential benefits that can be had from a well-organized, creatively directed industrial engineering program.

It would be quite easy to multiply this list of indications of negative or uninformed attitudes much further, and the answers in rebuttal could be expanded almost endlessly. The point is that these attitudes, for the most part, are not based on fact, and there is a wealth of evidence to prove it. Any industrial engineer with broad experience who is of a persuasive turn of mind should eventually be successful in most cases in shaping management attitudes towards greater recognition of the value of industrial engineering. He will increase his usefulness to management in proportion to his persistence in helping them to recognize the full value of an industrial engineering program.

But his efforts should not stop there. Our second point was that he must also help management to understand its role in the industrial engineering program. By stressing the benefits to be derived from industrial engineering, the industrial engineer may create the impression that he is going to produce them all by himself if management will just turn him loose. Nothing could be further from the truth. A successful program is the result of the cooperative efforts of a great many people. The industrial engineer may spark the program and he may do most of the technical work, but he will need the help of a number of other people and especially top management.

Let's look at it this way. The basic reason any management has for introducing industrial engineering is to improve methods and reduce costs. The very purpose of industrial engineering, therefore, creates problems. Everyone who has had management experience has undoubtedly noted that it is a human characteristic to resist change. People do not change their ways of doing things easily, and by people we mean both management and employees.

Cost reduction by its very nature means change. If costs are to be reduced from what they have been in the past, new and better methods must be found and used in the future. It is evident, therefore, that since it is human to resist change and since cost reduction through improved methods means change, there is in every organization a kind of built-in resistance to industrial engineering activities.

This resistance may be weak in the progressive organization, and it may be exceedingly strong in the more backward company. In any case, it is a factor that must be reckoned with by the management that wishes to introduce industrial engineering. The resistance can be overcome, but top management must furnish the leadership that is required.

The most important single ingredient for a successful industrial engineering program is the aggressive and sustained interest of top management. It is the one thing that can overcome on a company-wide basis the built-in resistance to change. Unless top management is convinced that methods improvement on a continuing basis is necessary for survival, the industrial engineers who are trying to make the improvements will find it difficult to accomplish as much as they otherwise could.

The wise industrial engineer will never oversell the ease with which methods can be improved. True, almost any factory or office is a gold mine of cost reduction opportunities. But the industrial engineer will need top management's help in realizing them. He should help top management recognize that it must make its contribution to the program

by reflecting at all times a strong will to make improvements. Methods improvement is never easy work. It involves study, planning, change, and a host of human problems. Unless the leader of the company shows a consistent interest in better methods and a never-satisfied desire to drive costs down and down, the others who look to him for direction and guidance are not likely to devote their full energies to the difficult work of improving methods.

As a third way of gaining recognition for the value of his work, the industrial engineer must take the initiative in establishing good cooperative relations with the rest of the people in the company, particularly the work force. Industrial engineering gets the greatest results in an atmosphere of cooperative, harmonious relations. Therefore, it is just plain good sense to do everything possible to see that such relations prevail. Good relations do not just happen. They are developed by careful planning and intelligent action. Although it requires action from both management and labor to secure true cooperation, the initiative for developing good relations clearly must come from management. As the chief representative of management in the field of his specialty, the industrial engineer should take the initiative in taking the mystery out of what he is trying to do by clear explanation to the people most affected.

Cooperative human relations with the workers are fostered in the field of industrial engineering by the following four conditions:

1. Understanding of and a desire for the social and economic benefits resulting from industrial engineering.

2. Mutual understanding of industrial engineering procedures and of the workers' problems and viewpoints.

3. Agreement on policies under which industrial engineering will be applied.

4. Thorough operator training.

There are others that could be listed which have a more or less direct bearing on the industrial engineering activity. The four mentioned, however, are illustrative of the kind of thing that will help enlist the cooperative support of the workers for the industrial engineering program.

Much has been written and said about the general benefits to labor resulting from a sound industrial engineering program. The most mature unions have accepted this and recognize that increased productivity will result in an increased standard of material well being for everyone. But the industrial engineer will gain more active support for his program if he will translate general benefits into the specific benefits his company and its employees will receive and present them in such a way that they are understood and accepted.

The work of the industrial engineer affects more or less intimately nearly everyone in the factory. It is not enough, therefore, merely to announce that an industrial engineering program is about to be installed and that the full cooperation of everyone is expected. People fear what they do not understand, and their instinct for self-preservation makes

them resist it. Therefore, before true cooperation can be obtained, an understanding must be developed of what industrial engineering is, how it works, and what it may be expected to accomplish.

The best way to do this is by means of formally organized training programs designed to develop an understanding of and appreciation for industrial engineering. Case examples taken from the plant should be used to illustrate the principles under discussion. Where a formal training program is impractical, the industrial engineer should try diligently to develop an equivalent understanding of his work through informal discussions. He should plan in advance what he would like to say and then seize every opportunity to tell his story. He should also seek to understand the problems of the workers and to conduct himself with sympathetic consideration of their viewpoints. This in time will break down the barriers which exist between the industrial engineer and the workers when understanding does not exist.

Agreement on policies under which industrial engineering is to be applied is a very important ingredient in cooperative human relations. The workers understandably are always trying to better their economic condition. If this is done in an orderly fashion during periodic economic bargaining at which policies, principles, wage rates, and the like are agreed to, a satisfactory compensation structure can be arrived at with a minimum of friction. On the other hand -- to cite the familiar situation where incentives are used -- if economic advantage is sought by questioning each new standard as it is established, by stretching the intent of the wage incentive plan to result in the payment of increased earnings without increased production, and the like, then an atmosphere of constant dispute and bickering will prevail. The establishing of a standard becomes a battle of wits between the worker or his representative and the industrial engineer. Hours and days are wasted in acrimonious discussion, and the relationships which develop are pleasing neither to management nor the workers. A situation of this kind can be avoided by straight thinking and a willingness on both sides to agree to and abide by the rules of the game.

Operator training is an excellent but often overlooked way of gaining worker support for the industrial engineering program. An operator cannot be expected to accept a new standard willingly and without reservation unless he knows that he can do the work within the allowed time. This assurance can be developed during the training period.

The industrial engineer has a definite responsibility for seeing that proper training is given to the work force. If he wants and expects the work to be done in a certain way, he must see that the operator is taught what that way is. If the teaching is done properly, it can be one of the greatest morale builders management can use. We have yet to see a properly organized training program that was not enthusiastically received by the workers. New workers absorb training eagerly, for they have a strong incentive to want to learn and to succeed. But even older employees who may have had ten or twenty years of experience on a job but who never have been given proper training, when finally given the opportunity to participate in a well-organized program, find it of the greatest interest. One old timer was heard to exclaim after leaving the training room on the first day of a well-designed training program: "I've learned more today about what I am supposed to be doing than I have in the past ten years."

When management gives evidence of interest in the worker's personal problems by sponsoring thorough training, not only is production increased because proper methods are learned, but it is also increased because of the attitudes towards the work which are developed during the program. It is often said that it is necessary to "sell" the worker on the correctness of a standard. A properly conceived operator training program not only sells the standard, but it sells the fairness of purpose of management as well.

We concluded our listing of the things the industrial engineer should do to obtain recognition of the value of industrial engineering by saying that he has the professional responsibility of being technically competent personally. If the industrial engineer believes in the benefits of his work to management, labor, and society as a whole, then he has the obligation to perform it competently. We had a clear lesson of the disastrous effect of incompetent work as the result of the "efficiency expert" era of World War I days. We do not need more lessons of the same kind. Industrial engineering has so much to offer to the people of the world, that every industrial engineer everywhere should make it his own personal responsibility to do the highest quality work of which he is capable.

Nothing succeeds like success. We said at the beginning of this discussion that there is much more to be accomplished by the application of industrial engineering in business, industry, and indeed, in all forms of organized human effort than has yet been done. The problem is to get those who either have not used it at all or who have confined the application to a narrow area to recognize the need for a sound industrial engineering program. The industrial engineer can contribute importantly to gaining this recognition by making every industrial engineering application he undertakes an outstanding success.

Many years ago when my old friend Dr. E. B. Roberts was Assistant to the Vice President in Charge of Industrial Relations at the Westinghouse Electric Corporation, he concluded a talk to workers explaining the benefits of industrial engineering as follows:

> ".....the American workman in very many of our important industries owes an important debt of gratitude to the improvements that have been made on his behalf by the studies and analyses of the efficient operational and manufacturing engineers during the past decade. Not only is the worker getting a better proportion of the total wealth being created, but he is being enabled to increase the total of that wealth. He profits on both accounts."

The same could have been said for management and for the American people as a whole. The industrial engineer has made a tremendous contribution to the record high standard of living which we all at present enjoy.

He is ready to contribute still more as the recognition of the need for an industrial engineering program spreads to more and more business and industrial enterprises. He must not sit idly by waiting for that recognition to come. His contribution is too badly needed. His self-imposed duty, and yours and mine, must be to speed the day when industrial engineering is universally accepted and used.

When that day comes, we will no longer be faced with spiraling inflation caused by increased wages and increased prices. Instead, we will have an economy based on ever-increasing productivity at lower and lower costs. And this economy will be sounder and stronger than any we have yet know.

RECENT ADVANCES IN OPERATIONS RESEARCH

Oscar A. Hoffman
American Machine and Foundry Company

I must say, right off, that I have approached this subject with more than a little fear and trepidation. This is because it seems to me awfully presumptive for one man, in half an hour, to cover the subject "What is new in Operations Research":- even when that man is one's self!

It must, from the start, be obvious to you that I don't have time to give you a very comprehensive coverage of the subject. Let me be the first to inform you that I couldn't if I had the time because there is much new work that I have not followed closely and probably a lot that I'm not even aware of. That fact, I feel, is indicative of one of the most significant of recent advances:- five years ago it was possible for a reasonably assiduous reader to keep up with most of the work being published. Now it's more like the Physics or Chemistry literature; one can only really keep up with a limited field and hope to be generally informed of important advances in others.

I must, therefore, either discuss only one or two specific areas or else try to give you my impression of the general trends. I shall be very timorous and have a try at the latter.

I shall do this by discussing four trends which I think I detect and which I feel are important. The first of these I shall call the Attitude of Professionals; the second the Structuring of the Profession; the third the Introduction of the Transient State and the fourth the Introduction of Experimentation.

Attitude of Professionals.

The changes in recent years in this area are important, in my opinion, because we are beginning to stop worrying and talking so much about it. Just as the Chemical Physicists and Physical Chemists have quit worrying over who's who, so the O/R people and their ideological neighbors tend more and more to leave off their fence building and to concentrate on cultivating the common ground. I think there is less concern with the label the work bears and more for the scientific calibre of the work itself. This is certainly an "advance" because now more of us have our eyes on the ball instead of the umpire.

This observation while brief, and possibly trivial in your opinion is important to me for two reasons:- First, as a professional I'm glad to have more people concentrating on what I'm doing rather than what I call it. Second, as your speaker I feel free to include any work which is scientific in nature and which is primarily concerned with the theory or practice of operations.

Structuring of the Profession.

This is probably a poorly chosen name for what I mean because I cannot give a brief, general definition of it. I am forced, therefore, to give you a probably too long-winded description:-

Five years ago the huge majority of people with any interest in or claiming the label of operations research were members of groups working on immediate, pressing problems. This is analogous to a technology in which all the physicists are working on the development of urgently needed equipment:- practically no one is doing so-called basic research or teaching. We were, in one sense, all engineering with little or no science behind us. In a situation like that many more problems are being stated than solved and the shortage of competent technologists gets more acute exponentially. There is also very little learning by exchange of information because all work done to solve immediate problems could also be of value to a competitor and is, therefore, subject to security restrictions.

Five years ago there existed outside the military:-

A few consultant groups,
One or two "short courses" in universities having a military connection,
A "club" in London that published a quarterly pamphlet,
One book on military O/R,
An NRC committee, and
A few "odd balls" employed by private industry.

Today there are:-

New Book by Wiley

Two U.S. and one U.K. professional Societies.
Three regular English Language journals.
Three American texts
Eleven major U.S. Universities with curricula leading to degrees.
Twenty additional universities offering one or more courses in O/R, and
At least four universities and one private institution having organized programs of basic research.

A part of what I've enumerated can, if you feel cynical, be passed off as a union movement. Whether it is or not, the thing of overriding interest to those both inside and outside the movement is the increase in publication, and, more important, the establishment of a basic research program.

M.I.T. has a graduate study and research program under the joint sponsorship of the Physics, Mathematics and Business Administration departments. An important portion of that program is an investigation of queuing theory. The ultimate objective of this program is to solve the queuing problem in its most general form and to publish tabulated parameter values and solutions in much the fashion that error functions or Bessel Functions are now available. They have fairly recently found a stochastic matrix formulation that will allow generation of results on the Whirl Wind II.

Carnegie Tech. and Purdue both have work underway on various aspects of transportation theory. I know none of the details of these programs but understand that their results will be made available in the general literature.

Case Institute is doing work on the theory of organization and communications. Results from this program are published in Research

Memoranda and, eventually, the recognized journals.

There is always, of course, the ubiquitous Rand Corporation. Probably the most important and best known of their unclassified basic research is in the field of programming theory. In fact, there is a man who can be called the leader in this subject; it is Richard Bellman of Rand Corporation. (For those of you interested in this subject, in the September '56 issue of Industrial and Applied Mathematics Bellman published a paper which reviews the area of programming problems under investigation. He cited 62 papers and books dealing with programming theory of which only four were published before 1950.)

If you'll forgive me the analogy, I can summarize the point I'm trying to make by saying that we've progressed from having just power reactors to possession of breeder reactors. We are not just giving young people a broader foundation than the apprenticeship methods of ten years ago but we are breeding ideas by the publication of generalized problems and - sometimes - solutions.

This is not to proclaim a bright new world of tidy, "optimized" operations. What is claimed is that O/R as a branch of science and a factor in the economy has begun its weaning.

The bulk of new comers to the field are still coming from other professions but the training operation is established and needs only time to grow and feel its way to maturity. There is still a lot of reasoning by analogy but more and more of the papers coming out show a direct attack on the problem at hand. More and more one finds it profitable to start a new problem with a literature search.

Introduction of Transient State.

Most of the work done in the past has been for system in a steady state. That is, the parameter values are invariant with time. For example, a production schedule is constructed in terms of a sales forecast and set of inventory policies. The solution is assumed valid for the duration of the sales forecast period.

There are many situations in which the assumed conditions do not hold and the usefulness of the scheduling techniques are correspondingly limited. For example, the business with which I am primarily concerned - contract engineering is one in which scheduling is vitally important. One must schedule in terms of the anticipated work load, yet the acquisition of new business can be effected by the way one schedules. The operation, is in brief, constantly in a transient state and new ways must be found to deal with it.

There are several general ways of getting at this dilemma, and the important advance I'm trying to point out is that they are being tried. We find ourselves dealing more and more with transient state problems.

One can take what might be called the linear approximation method; that is, periodically resolve the problem with a new set of parameter values. If the system is in a state of rapid change this can get expensive. An antidote for that is to make the work more efficient and this is, in my opinion, one of the mechanisms that leads to the importance of computing machinery in Operations Research.

Another approach is to attack the transient character of the problem directly. This is what Ferguson and Dantzig did in their work on Linear Programming under Uncertain Demand and what others are doing in developing the theory of Dynamic Programming.

As Bellman himself points out in the article I referenced earlier, the problems are very difficult and in many cases the basic mathematical tools do not exist. I'd like to add to the opinion that this comes about because we are attacking operating problems directly instead of by analogy and their peculiarities are beginning to show. We can't make so much head way as we used to borrowing tools from physical science and engineering. In this sense we will be depending more and more on the academicians I referred to before because we are well into a period of tooling up.

Experimentation

Somone recently - I've forgotten who it was but I think I read his words in Management Science - chided the O/R people for not doing more experimentation. This has a familiar ring to me for I can remember much philosophizing a few years ago to the tune that if you meddle with a system you change it. Poor us! We're denied the easy out of the physical scientists!

To some extent I think the lament valid. Certainly it's more difficult to experiment in some fields than in others, e.g., electricity compared to human genetics. However, some experiments have been tried and others are in progress. This is, in my opinion, a very important move in the right direction. Our problem of uncontrolled & irregular input for use in queuing may be reduced to data; may be too complicated.

The December 1956 issue of Operations Research has an article by Dunn, Flagle and Hicks on the "Queuiac" - a machine for experimenting with complex waiting line problems. This is a type of problem in which the behavior of component parts of a complex system can be fairly well understood. However, the coupling effects among the component parts of the system are so many and complex as to make an analytical description of the entire system virtually impossible. I am referring to systems where members of the line arrive from several different sources or where there are queues in series, or where the statistics of the process cannot be expressed in closed analytical form. The Queuiac simulates the components of the operation and allows one to experiment with an entire system. One can observe queue's length directly and get empirical estimates of transition probabilities.

A composite group from Rand, several companies and the AMA have put together a game board procedure that simulates a competitive business situation. Each of several players is in complete control of the manufacture and distribution of one brand of a given product type. These brands are in competition and the payoff to each player is his share of the total sales. He has control of expenditures for promotion, product improvement, production rate, etc. He makes his play by allocating his resources and observes the effect in sales volume and market estimates.

The rules for the game are many and complex (and in some cases probabilistic) and based on observations of real business experience. They are programmed for the IBM 650 which accepts each player's move and computes the new market situation.

While the AMA is primarily interested in this as a teaching tool, it can be a very useful experimental device for studying the relationships among such things as gross sales, return on investment, profit margin, net worth, etc.

These two cases are mentioned in detail as illustrative of what I mean by experimentation. They do not by any means cover the field because there is much experimentation that can't be talked about or isn't yet far enough advanced to merit public discussion. For example, my own group is just now working out an experiment to study the effects of individual estimators on bidding strategy. We hope to have something to describe about six months from now.

Summary

I have described four areas in which I think there has been important advance in the last few years. Two concerned the O/R professional and his profession and two concerned the substance of his work. These things are not independent but are interrelated and taken together represent a significant gain in maturity. The field is, each month, less of a mystery and looks more and more like any other branch of science.

I should like to conclude by pointing out that probably the most important aspect of these recent advances is their extrapolation into the future. There will probably be a greater than linear increase in teaching and "basic" research over the next few years with a concomitant shortage of competent personnel. There is already visible what Dr. Ellis Johnson has called the "attenuation of talent" arising out of the facts that most training is still by apprenticeship and new groups are coming into existence faster than fully trained directors for them. The result is partially trained people undertaking the training of new men. This, to me, indicates a period coming up during which the consumers of O/R should exercise both caution and patience. It will be even more important for the practitioners to maintain rigorous personal and group standards.

We must still proceed slowly.

In terms of the substance of O/R work, there are, right now, important concrete problems in programming, queuing, and gaming that are stalled for lack of mathematical know how. Fundamental advances in variational calculus, group theory and small sample statistics are needed to further the affairs of practical business men. We are, in brief, faced with a "tooling up" period. Outward advances of real import will come slowly and the signs of advance will, in many cases, appear first in the mathematics journals.

My remarks have been necessarily general. I hope not so much so as to bore you. There is, I believe, a question period during which we can be as specific as your interest and my knowledge will allow.

Thank you.

PROFIT PLANNING AND RESPONSIBILITY REPORTS

J. Curran Freeman
Dresser Industries, Inc.

It would not be taken amiss if some among you would wonder at the presence of a Controller on the program of this your Annual Conference of the American Institute of Industrial Engineers.

Let me assure you that it is an honor to be here; allow me to say further, as a representative of a Company intensely interested in the application of the principles of scientific management, I appreciate the opportunity to review the salient features of the Dresser Industries' organization, its operations planning and control.

As you well recognize, planning and control programs differ in their design and application depending upon the nature of the business and the specific organization of the company. A brief review of these details regarding our Company will serve as background material for understanding and evaluating our program.

Organization

Dresser serves the oil, natural gas and petro-chemical industries. Its eleven operating companies are organized around a policy of decentralized authority and responsibility. The parent company is organized on both a line and staff basis, with heavy emphasis on the latter. In addition to the Chairman of the Board, the President and the Vice President, Secretary and Treasurer, it has three Operating Vice Presidents, whose individual activity embraces one of three divisions, capital goods, drilling and expendable and oil tool. The Operating Vice Presidents are the direct link in the chain of command between Dresser top management and the managements of the operating companies. In addition there is an operating staff composed of specialists in the fields of manufacturing, engineering, advertising and public relations, industrial relations, foreign operations, patents, and marketing research; as well as a financial staff composed of specialists in the areas of business research, control, legal and taxes, purchasing, traffic, and shareholder relations. No company the size of an average Dresser company could individually afford staff organizations such as these; together, however, they can and do make optimum use of each.

Dresser has a Management Development Committee responsible for its executive training program. This program utilizes outside agencies, such as outstanding universities, the extensive facilities of the American Management Association and highly developed internal programs to keep abreast of new and more efficient management techniques.

An organization, such as ours, national as well as international in the scope of its activities cannot function effectively on hunches, opinions, or guesses; it must generate facts - raw data for management decisions - by a conscious and orderly approach in the analysis of all the facets of its business. We identify the result of this intensive analysis as the Dresser Industries' Profit Plan, which is in truth a "Blueprint of Action".

Planning

The plan, as you might suspect, must be operational as well as financial in scope, covering in detail market analysis, sales forecasting, production and facilities planning, distribution, capital investment and return, and management development.

The basic period covered by the plan is a fiscal year, with further schedules providing for a longer period of five years and ten years.

Each year a profit plan meeting is held in Dallas in order to afford the management of each of our operating companies, individually, the opportunity for a full day's conference with Dresser top management to discuss the ensuing fiscal year in detail and the five year and ten year projections in broader terms. During the meeting three important areas are discussed; the operations projection, the financial projection and management development.

Under operations projections the following detail is searchingly reviewed:

Sales - planned changes from prior fiscal period product line unit and dollar sales levels; product mix, prices and variable margins; planned penetration of selected industry markets, both domestic and foreign; product and market research and development programs; changes in breakeven sales levels.

Production - planned changes in production techniques, quality and performance; material and conversion cost (direct labor and variable manufacturing overhead), as well as manufacturing expense, particularly the level of fixed manufacturing expense; inventory levels and the relationship between production, inventory and sales levels by product line, production facilities, current and projected five years hence.

Operating expenses - planned changes in levels of selling, engineering and administrative and general expense, particularly the level of fixed expense if changes are significant; market research programs and methods of distribution; product research and development programs.

Operating profit - comparison of actual operating profits of current year to profits planned for ensuing year based on profit implications of the foregoing changes. Comparison with respect to operating assets, fixed assets and gross asset turnover are important as between the two periods.

Under financial projections careful analysis is made of planned changes in current assets and liabilities, cash position, as well as source and use of funds provided and used in operations. Finally, profits from operations, capital turnover, and return on assets employed, each on a current and trend basis, are developed as a determinant of the efficiency with which an operating unit is managed.

Control

Planning is fascinating; however, it remains academic unless the plan is subject to regularly scheduled review and comparison with the results of operations. Certainly there are no more pertinent observations in this respect than those of Frederick W. Taylor to the effect that management should receive concise, summarized and comparative reports. In our routine of reporting we believe that operations reports should be prepared by area of responsibility for each level of management beginning with the foreman. We believe that these reports should first and foremost be timely. We see the necessity for daily reports, for example labor input and labor output; daily shipping and billing reports; weekly reports of manufacturing expenses; interim cost reports on completed parts, assembly or manufacturing orders; periodic inventory status reports, preferably on a perpetual basis; monthly reports of operating expenses; monthly inventory turnover reports by product; monthly sales reports by product, territory, salesmen, and market; monthly summary operating reports and customary financial reports, profit and loss and balance sheet.

I should like to submit for your consideration and discussion a monthly summary of operations, a report which is under study by our controllership team. We think of it in terms of a one page report for top management, executive, manufacturing, sales and financial embodying the basic and essential information for quick, concise and meaningful summary of results in terms of:

Breakeven sales
Product mix
Operating profit
Variable costs
Fixed costs
P/V ratio (variable margin)

together with minimum explanatory comment on significant deviations from plan.

The P/V (profit to volume) ratio is not unfamiliar to the industrial engineer. With the renewed interest of the accounting profession in direct costing, it becomes a significant ratio for executive management. Departing from the "whole cost" concept of cost accounting, with its essential proration and allocation of fixed expenses, one is able to quickly evaluate the effects of volume on profits. Recognizing that there is an individuality of product profit contribution, the effects of mix and spending variations of direct costs (material, labor, and variable overhead) may be more readily ascertained and remedial action taken where required. This approach implements the standard of performance concept; facilitates control over operations and thereby augments profitability. We believe that this report significantly embodies the "exception principle", advanced years ago by the industrial engineer as an aid to improved management efficiency.

We shall refer toward the close of this paper to the mutuality of interests which you as industrial engineers and we as controllers share. Allow me to suggest that there is no more profitable area of interest and cooperation in this respect than the establishment of

cost and other standards of performance followed by intensive analysis and review as members of the cost engineering committee. Therein the industrial engineer, the cost accountant, the design engineer, and manufacturing management combine their talents and experience in profit improvement studies. Those experienced in manufacturing activities keenly realize that while profit potential is frozen in the design it can be lost or at least minimized in the conversion process through improper control and lack of communication. Cost reductions, often of major significance, are reported as the result of this type of interdepartment activity and liaison.

This review of our philosophy of planning and control has of necessity been brief; we believe that it has been sufficiently definitive to prove that conscious and orderly procedures and methods can be successfully employed by all echelons of management.

A discussion of this general subject would not be complete without reference to the concept of "feedback", a technique advanced by Alex W. Rathe in "How To Set Up Management Control". Relative to our subject, he says,

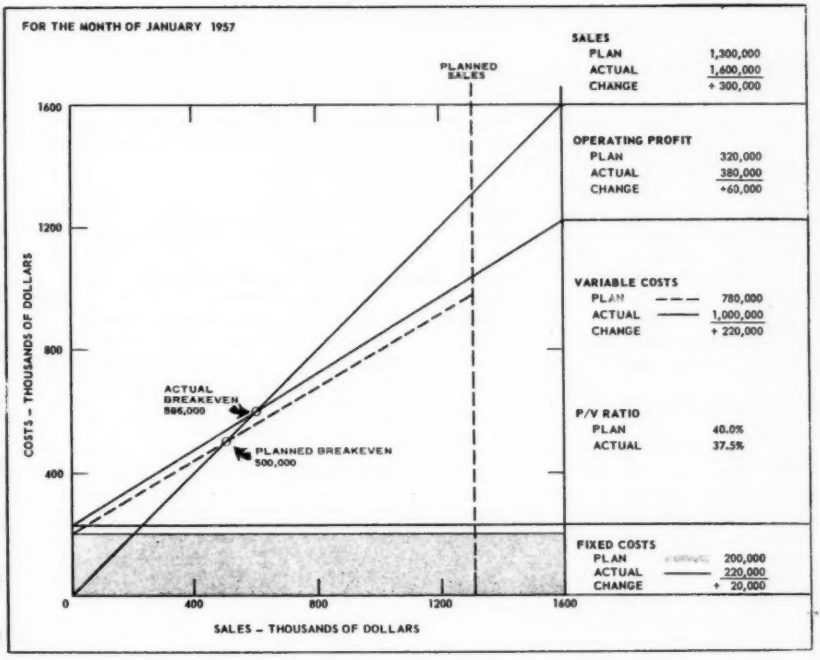
> "Planning establishes targets and determines how they can best be met -- Review gauges the success of operations and interprets their results in order to draw conclusions for possible improvements -- Feedback becomes the link between planning and review so that one can benefit from the other, so that the elements of the management cycle are jointed together to give it continuity. If the results of review were not channeled back into the planning stage, some of the lessons of experience would be lost forever."

Our profit plan is a guide post, not a hitching post. Our company is a growth company; dynamic not static; hence we currently measure results against plan, and re-evaluate the plan quarterly by projecting it twelve months, thus capitalizing on the lessons of experience.

It is hoped that we have shown you something of the controller's interest in and use of the principles of scientific management; that we have indicated areas of collaboration which can be more actively pursued within your individual companies.

There is a strong conviction on the part of many controllers that our greatest potential for increased organizational effectiveness rests with the more widespread use of the principles and techniques advanced by your profession. With slight modification of the definition of the professional engineer, I submit that we could document the mutuality of our interest by the addition of one word and the deletion of the other. Therefore, we suggest that, in addition to other areas of responsibility, the controller is also "concerned with the design, improvement, and installation of integrated systems of money, men, materials, and equipment; drawing upon specialized knowledge and skill in the mathematical, physical, and social science together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems."

BLANK COMPANY
MONTHLY SUMMARY OF OPERATIONS



Comments:

1. Sales up $300,000 due to:
   a. Product Mix

PRODUCT LINE	PRODUCT LINE P/V	CHANGE
A	50%	-100,000
B	40%	+200,000
C	30%	+200,000
		+300,000

   b. Price level changes — none

2. Variable Costs up $220,000 due to:

a. Product Mix	+210,000
b. Efficiency & Other	+ 10,000
	+220,000

Efficiency variance shown above due primarily to: Overtime premium 6,500; Defective workmanship 2,750

3. Fixed Costs up $20,000 due primarily to increases in: Factory superintendence 1,200; Property insurance 1,000; Rent 1,200; Depreciation 2,100; Property taxes 2,650; Emergency repairs 9,500.

HOW TO SET UP AN INDUSTRIAL ENGINEERING DEPARTMENT

Edward E. Querbach
American Cyanamid Company

Introduction

It is a pleasure and a privilege to share with you some experiences in setting up an Industrial Engineering Department. Inasmuch as this is a case history, some background information concerning our company and its organization might be in order.

The American Cyanamid Company began construction of its first plant in 1908 at Niagara Falls, Ontario. A year later, the first calcium cyanamid was produced. Since that time, the Company has grown until it now operates over 40 plants, mines, and major research laboratories in the United States and foreign countries. It has approximately 24,000 employees. Gross sales for 1956 exceeded $500,000,000. A wide variety of products are manufactured for industry and the consumer, including fertilizers, insecticides, pigments, dyes, explosives, ethical drugs, veterinary medicines, surgical products, and chemicals for industries such as, rubber, metals, paper, leather, textiles, and many others.

The Company is organized into divisions by product groups or service function. Each producing division is responsible for the manufacture and sale of its products, and the General Manager of each division reports directly to the President of the Company. The General Staff of the President is composed of seven Vice Presidents, each with his own area of activity.

At the Company level, a Central Industrial Engineering Department reports to the Vice President for Engineering and Operations. As a staff department, it is responsible on a company-wide basis for:

(a) Promotion of the proper use of Industrial Engineering
(b) Determination and selection of Industrial Engineering methods
(c) Selection and training of Industrial Engineers
(d) Audit of methods and results

Members of this department act as consultants to the various company divisions and plants in carrying out the aforementioned responsibilities. It is in this capacity as staff consultants that the Central department has been called upon over the years to develop Industrial Engineering programs for plants and to assist in their implementation.

Within the framework of the divisions, there are permanent Industrial Engineering groups at twelve of the larger plants. Depending upon the scope of operations, each of these groups reports either to the General Manager of the division or to the local plant manager. The relationship of the Central Industrial Engineering Department to these groups is strictly staff.

Development of a Plant Industrial Engineering Program

The plant selected for this discussion, the Lederle Laboratories at Pearl River, New York, manufactures and packages a wide variety of pharmaceutical and biological products. It is the largest plant in the Company, with about 4,500 employees. Operations are varied and complex, offering a challenging opportunity to Industrial Engineering. Initially,

a survey of the Lederle plant was made to establish the broad outlines of an Industrial Engineering program. As with any Industrial Engineering program, the major objective was cost reduction. It only remained to determine the How, Who, and When of the program.

Any program to be successful must be tailored with consideration for the size and kind of industry, the organization and traditional grouping of functions within the organization.

The broad, over-all program took the following form:

(1) Development of a program suitable to the needs of the plant, taking into consideration the scope, areas of effort, functions, and time table.

(2) Development of the organization to carry out the program.

(3) The necessary training of the personnel.

(4) The selling of the program to the various levels of management and the union.

(5) The implementation of the program.

Industrial Engineering Program

In the process of developing a program, many plant activities will be found to which Industrial Engineering techniques can be applied to obtain improvement. They will require different degrees of effort with varying results. Careful evaluation is, therefore, necessary in order that areas finally selected will produce results adequately justifying the cost of making the improvement.

This evaluation will usually consist of a study of organization charts, manning tables, flow charts, layout, and operations. Local policies and conditions should be discussed with supervision to understand the reasons underlying existing situations. Having obtained this background, selection can then be made based on the following guides:

Select: (1) Areas which can be readily analyzed, measured, and controlled.

(2) Areas where a single controllable factor such as labor or material is a major portion of the cost.

(3) Factors for improvement which are within the control of supervision.

(4) Labor areas which offer the best opportunity for improvement. These may include areas where operations are repetitive or semi-repetitive in nature; where the same grouping of skills predominates such as a maintenance craft; or where groups of employees are performing identical or related tasks.

Areas requiring substantial research, development of new techniques, or other long-term factors should be reserved for the latter part of the program.

Applying these guides to the Lederle Plant, it was decided that the initial effort would be made in,

(1) Filling and Packing
(2) Maintenance
(3) Bulk manufacturing
(4) Warehouse and Shipping

This priority is based on the population of each function, the magnitude of the result expected, and the anticipated ease with which measurement can be made and controls established.

The balance of the effort to be applied at a later date includes administrative services, housekeeping, utilities, and miscellaneous services.

The purpose of Industrial Engineering is to assist management to obtain maximum production of high quality goods or services with a minimum expenditure of manpower, equipment and materials. This can be realized by a critical analysis of the components of cost, by elimination of wasteful usages, and by increasing the productivity of the organization. Applied to manpower, equipment, and materials, this approach includes the following fields of study:

Manpower -
- Analysis of Usage
- Organization of Skills
- Work Loads and Standards
- Compensation

Equipment -
- Methods Analysis
- Materials Handling and Layout
- Size and Number
- Thru-put Determination

Materials -
- Analysis of Usage
- Substitution for Greater Economy
- Packaging Components
- Control of Container Costs

Normally, a plant Industrial Engineering group will function in all of these fields. This may be limited, however, by the fact that a group in the local organization may already be established in one of these fields. At Lederle, compensation is a function of the Industrial Relations Department and includes both wage and salary evaluation. Salaried organization studies and systems and procedures are a function of the Management Planning Department.

Based on the four areas selected and the functions as previously outlined, the following program was recommended:

Analysis

(1) Proper methods, physical layout, and equipment to accomplish assigned tasks, including design of new jigs or fixtures where desirable.

(2) Material handling and plant layout studies.

(3) Economic studies of new equipment recommending where desirable purchase of the equipment, the extent of its application, and the potential savings.

(4) Review of all budget requests relating to equipment, layout, new processes, and similar subjects.

Measurement

(5) Man-hour standards for labor operations including production, set-up, and change-over.

Controls

(6) Standard manning for all operations manned on a group basis.

(7) Production standards for specific product groups to aid in production planning and scheduling.

(8) Variable budgets indicating salaried personnel required at various operating levels.

(9) Conversion of Accounting Department standard costs from an historical to an engineered standards basis.

Proposed Organization

At the time of the survey, several Industrial Engineers were working in the plant, each responsible to the head of an operating section. Each of these engineers was working on day-to-day problems within his section without a planned forward program for the plant as a whole. The efforts of these engineers were not coordinated between operating sections. In short, their effectiveness varied directly with the knowledge possessed by each section head as to the scope and application of Industrial Engineering techniques. Thus, it became apparent that in order to obtain maximum effectiveness, a centralized effort would be necessary. This decision created the problem of where Industrial Engineering should be placed in the plant organization, whether the function should report directly to the Plant Manager or through an intermediate executive.

The first option, that of reporting to the top executive, places Industrial Engineering on an equal status with other major functions. It offers the largest field of operation with access to all groups within the organization. Industrial Engineering then has the opportunity for maximum service to management.

The reporting relationship finally selected will depend upon a number of factors, which include:

(1) The existing plant organization - its size and complexity.

(2) The number of subordinates reporting directly to the top executive.

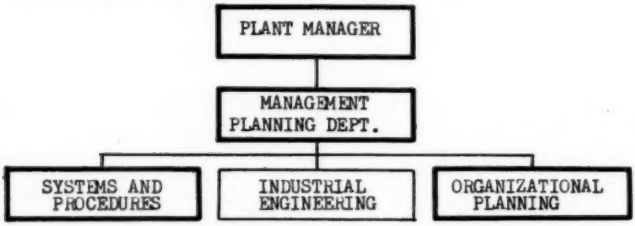
(3) The objectives of the various groups in the plant organization.

(4) What Industrial Engineering functions, if any, are currently being performed, and by what group or groups.

Here is how the problem was handled at Lederle. Eight major operating functions reported directly to the Plant Manager. Thus it did not appear desirable to increase his span of control by adding a ninth function.

The existing plant organization included a Management Planning Department, reporting to the local top executive. It was staff in character and plant-wide in scope of operations. Among its announced objectives were to recommend sound organization structure, to assist top management in establishing performance standards, and to develop methods, systems and procedures for handling administrative work. All of these objectives are in the field of Industrial Engineering. Here then, was the logical place to concentrate the Industrial Engineering effort, adding to it the presently decentralized engineers, as well as, the other functions necessary to carry out the complete program. Thus, the nucleus of an Industrial Engineering group was formed within this department, utilizing the three engineers previously assigned to operating sections and augmenting them with skills from outside the plant. A total of nine engineers and a supervisor were recommended to start the program. Ultimately, a full-scale program may require twenty to thirty engineers.

The resulting organization looks like this:



The heavily outlined blocks represent the original organization. Each group has a supervisor reporting directly to the Manager of Management Planning. Major projects frequently require formation of teams with representation from all three groups. Hence, there is considerable exchange of service.

Internally, the Industrial Engineering group is organized to parallel the production organization with a Senior Engineer responsible for the work in each major area. Junior engineers are assigned in accordance with the workload. Any project outside the production area is handled as a special assignment by any member of the group.

Training Techniques

In formulating a training program, consideration must be given to the needs of the particular plant and the previous training of the group. Analysis indicated, in our case, a need for training in measurement techniques, such as, work sampling and time study levelling, as well as instruction in company policies with respect to Industrial Engineering.

This training was accomplished at staff meetings. In addition to training, such meetings offer opportunity for discussion of major problems and exchange of information.

This has been supplemented by attendance at packaging seminars and conventions as well as meetings of professional societies. The group keeps abreast of the latest developments in the packaging field through trips to equipment manufacturers and other pharmaceutical houses and through study of trade literature.

A reference library is available including an Industrial Engineering Manual prepared by the Central Industrial Engineering Department and recent publications in the field.

Formal training was given in a pre-determined time system which was selected as an alternative to stop watches.

Several pre-determined time systems were studied in detail. Of these, Methods-Time-Measurement, or MTM, was selected because its basic classification of motions best suited our needs. It required a shorter training period and was less expensive to install than some of the other systems considered.

For those of you who may not be familiar with Methods-Time-Measurement, it is a procedure involving analysis of a manual operation or method into the basic motions required to perform it. To each motion is assigned a pre-determined time standard which is determined by the nature of the motion and the conditions under which it is made.

A consulting firm, which is a member of the MTM association was engaged to conduct in-plant training sessions as well as a week of guided application at the completion of the course. Opportunity was extended to selected members from production, as well as Industrial Engineers from other plants in the company, to participate in the course. Those who successfully completed the course and the written examination were given certificates of recognition by the MTM Association.

Selling the Program

The first step in selling the program was completed with its approval by top management. Detailed plans of application were then developed with the heads of the various operating sections. This was the second step in selling which must be done at all levels of the organization. It continues daily with the advent of each new project or important phase thereof. Selling is a way of life rather than a one-shot procedure.

Section supervisors must clearly understand the job to be done and the benefits to be expected. Once this has been accomplished, it is expected that they will secure the understanding and cooperation of all concerned within their organization. This does not eliminate the cheek by jowl relationship which must be maintained between the Industrial Engineering groups and all levels of the organization. The work of the world is accomplished at all levels, not just at the top.

The importance of complete selling cannot be over-emphasized. This was brought home to us at an early date with the introduction of our first methods improvement, which was a jig designed to convert a one-hand hold to two hands doing useful work. Apparently, the jigs were issued to the packing lines at 7 A.M. before the supervisors were instructed in the method to be used, or the work place layout. You can imagine the situation by the time the Industrial Engineer reported for work at 8 A.M. Several different methods and work place layouts were in evidence.

Remedial measures were promptly taken by individual instruction to the supervisors. However, that first wrong impression remained to make the selling and success of this project considerably more difficult.

During development of the detailed plans of application, the method of approach to the union and the hourly employees was discussed with the Production Manager and the Industrial Relations Department. Several recommendations resulted:

(1) That a 4 or 5 hour course be conducted for first-line supervision and union stewards to explain Industrial Engineering and time study; discuss the tools and techniques to be used; and explain the difference between work simplification and speed-up.

(2) To begin in areas that did not involve stop watches. It appeared desirable to the Industrial Relations Department to postpone use of stop watches until a solid working relationship had been established between the hourly employees and Industrial Engineering.

(3) That the approach to the union and hourly employees was to be based on expansion of existing Industrial Engineering activities rather than a new function in the plant. This method of approach later resulted in reduction of the indoctrination courses from the recommended 4 or 5 hours, to one hour each.

The meeting with the union executive committee covered the objectives of Industrial Engineering, its areas of activity, that part of the Industrial Engineering program which concerned daily contact by our engineers with hourly employees, and the Industrial Engineering techniques to be used. During this discussion, the union raised the question of stop watches. Our reply, that the stop watch is a recognized Industrial Engineering tool and would be used when necessary, brought no adverse reaction. Similar meetings using the same format were held with first-line supervision. Indoctrination was completed with distribution of a letter to hourly employees emphasizing centralization and expansion of existing Industrial Engineering activities.

One other relationship had to be reaffirmed before starting the program. This was to reassure supervision as to the staff relationship of Industrial Engineering. No line authority would be employed. Contact would be with first-line supervisors, who would relay any instructions to hourly personnel.

Later, when Methods-Time-Measurement was introduced in the plant, an appreciation course for supervision and union representatives appeared desirable. Among other things, the course should discuss basic MTM principles, the advantages of MTM over time study, as well as, develop acceptance by the union of its use as a common base for settlement of standards problems. Choice rested between a standard 16 hour program given by the consulting firm, and a shorter program prepared by Industrial Engineering. Final choice was a one-hour lecture given only to supervision. Was this the proper decision, to exclude the union from these discussions? Would it be more difficult, later, to sell MTM to the union, perhaps at a grievance meeting? One can only conjecture, since a test case has not yet arisen.....

Implementation of the Program

Now let's discuss some of the problems encountered during implementation.

The program started in the Filling and Packing Section, the largest single group in the plant numbering over 450 employees. As you may recall, our first objective in this section is to provide management with measurement standards necessary to properly schedule work, and to obtain the most efficient use of manpower and machines. From the beginning, we were confronted with the prospect of a tremendous volume of these standards. Work already done was based on one standard for each product and package style. Additional standards were required for each packing line that the product could be run on, and for each type of inventory produced. With all these options, the existing 800 product and package styles could result in over 5,000 standards, requiring many hours of engineering and clerical work to establish, much less maintain them up-to-date.

After some study, a new basis for issue was developed. Each standard would, in effect, describe a method for filling and/or packaging a broad type of product, such as, liquids, capsules, or tablets in a particular package style, container, and packaging specifications.

Note the three major sections of a standard shown on Page 9. The first section at the upper right identifies the standard by the information contained on the first line, recaps the personnel required, and indicates the production rates. The second section at the left describes the operations to be performed in their proper sequence, and indicates the number and type of personnel assigned to each operation. The third section at the bottom is a schematic diagram of the packing line equipment indicating where the personnel are to be stationed.

Referring to the identifying line at the upper right, the packaging specifications in this case call for a label and a printed box. All of the requirements specified on this first line are frequently common to more than one particular product. Thus, it is possible to cover numerous products with one standard, as shown by the example which lists four products. Often, a product can be added to a standard without a production study simply by verifying that the product characteristics, packaging components and specifications are identical with those on the standard. This is the key to our new system which has reduced the anticipated total from 5,000 to 1,500 standards.

The time required for the work measurement has been shortened through the use of MTM. Several features of pre-determined time systems make this possible. First, the pre-determined times constitute levelled elementary standard data which must otherwise be developed by time study. Second, having once seen the operation, the engineer can accurately synthesize methods and operation times without making further studies. Third, this system lends itself to the derivation of time formulas which substantially reduce the number of studies required to cover a given range of operations.

An interesting application of a time formula, which has been reduced to a nomograph is shown on Page 10. It covers the operation of breaking (or opening) a flat carton, closing the carton bottom, and laying it aside on the table. The total operation time in TMU's can be read in the center column by aligning a straight edge between the desired

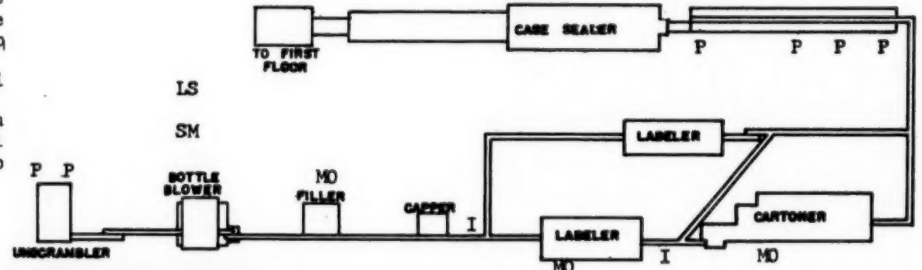
PRODUCT - PKG.	CONTAINER - PKG. SPECS.	INV.	LINE	EQUIP
Liquid - 58	0321 - DM	4	2	1

INSPECT.	MACH.OP.	PACKERS	OTHER	TOT.PERS.	UNITS/LINE HR.	UNITS/LABOR HR.
2	3	6	2	13	4320	332

ISSUE DATE 8.9.55 REPLACES STD. ISSUE DATE Old Form

PROD. NO.	PRODUCT NAME	APPROVAL DATE	PROD. NO.	PRODUCT NAME	APPROVA DATE
4149	Folvron Elixir, 4 oz.	12.12.56			
4303	Vi Delta Emul.	12.12.56			
4354	Lederplex	3.16.55			
4515	Hetrazan Syrup	12.8.56			

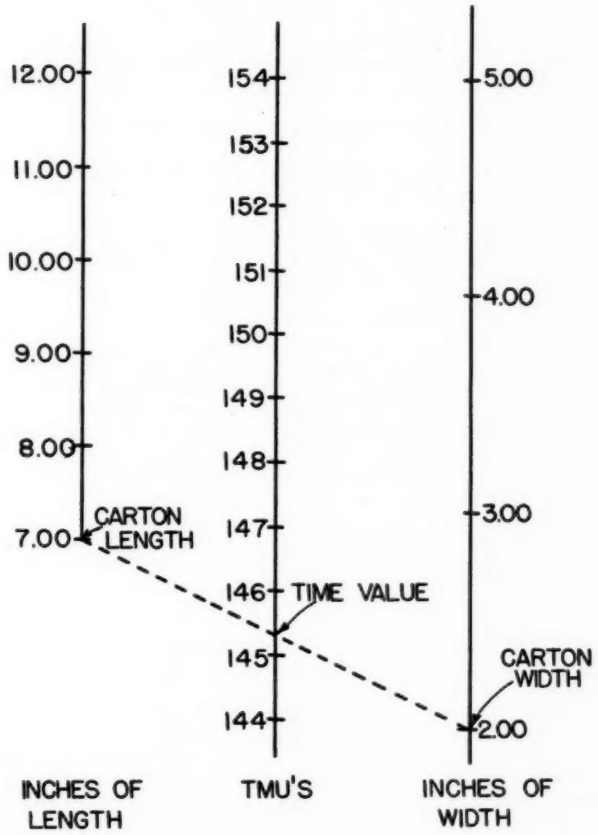
OPERATORS NO.	OPERATORS TYPE	OPERATION
1	P	Pick up reshipper from pallet; fold back top flaps place on table next to unscrambler.
1	P	Dump (12) bottles from reshipper onto Machinery Service Unscrambler; bend end flaps in; place on overhead conveyor.
1	MO	Operate Pneumatic Blower; Majonnier Filler; Consolidated Capper.
1	I	Inspect for cap; fill, foreign objects, etc.
1	MO	Operate Pneumatic Labeler
1	I	Inspect cap, label, etc.
1	MO	Operate Jones Cartoner
1	P	Transfer empty reshippe conveyor to lower conve place 4 boxes in reship
2	P	Pick up 2 boxes at a ti
1	P	Check for full count in fold in end flaps; pull allowing it to push lab sealer.
1	LS	
1	SM	
13		Total



STANDARD OPERATING PROCEDURE

TIME FOR FORMING, CLOSING & LAYING ASIDE PLAIN WHITE CARTONS 7" AND OVER IN LENGTH

FORMULA T = 137 TMU + 1.7 TMU / INCH OF WIDTH + 0.7 TMU / INCH OF LENGTH



length on the left and the width on the right. Actual studies on only three carton sizes were required to develop this formula and one other, which together cover 120 existing cartons, and, incidentally, any others that may be designed within the limits of the size range.

Our second objective is to report performance based on these standards, and assist management in the interpretation and analysis of this performance. Reports will be required weekly and perhaps daily to enable management to take positive corrective actions and to improve performance. Preparation of these reports, involving the details of over 125 finishing orders daily, should be done with a minimum of clerical effort. With this goal in mind, we are considering the use of an electronic reporting system, such as, "Automatic Production Recording" designed by International Business Machines. With such a system, pertinent data would be reported electronically, either by sensing devices or by a packing line supervisor. A central console would collect these data and convert them either to punch cards or tape. Ultimately, the cards or tape could be combined with other information in a computer, and a performance report issued within hours after the close of the business day.

Summarizing the important phases of this discussion, they include:

(1) Careful analysis of the needs of the organization with a program tailored to fit those needs.

(2) Creation of an Industrial Engineering organization reporting at the proper level to insure accomplishment and staffed with qualified personnel to carry out the work.

(3) Careful and continuous indoctrination, training, and selling of the program.

Finally, with an eye to the future, the Industrial Engineering organization should study and evaluate new areas and frontiers where they may enlarge and improve their service to management.

CENTRALIZED DATA PROCESSING IN A DECENTRALIZED COMPANY

Leon C. Guest, Jr.
Sylvania Electric Products Inc.

Some economists over the past few months have professed to have seen a subtle and only faintly discernible change taking place in the American economy. What has been taking place in business and industry, as well as the policies that some Government agencies have adopted, suggest, these economists say, that we may be veering into a period of deflation after several years of combatting severe inflationary trends. I am not going to review the events that have caused these economists to have raised the possibility of deflation, nor am I going to comment on the logic of their suggestions. For my own part, I prefer to see what evidence the balance of the year 1957 provides, before I will draw firm conclusions as to whether the economy is changing, and if so, in what direction.

Earlier this year we read in the financial reports of many of our industrial and commercial companies that, although new sales records had been attained, profits were somewhat below record levels.

So, we are confronted by two possibilities:

1. The possibility — and I repeat that it is only a possibility — of a move by the economy in the direction of deflation.

2. The possibility that lower profits by some companies in some industries might develop into a more general trend.

***** ***** ***** ***** *****

I believe emphatically that one of the strongest courses of action to prevent these two "possibilities" from becoming actualities is a critical examination of the factors making up the costs of our products and services. This critical examination will have to be a virtually unanimous effort on the part of all our businesses and industries. It will have to be unanimous because, first, the economy is made up of the sum of our efforts, and, second, because the elements of cost vary for each organization, and some elements of cost are more controllable than others.

The question of overhead control, however, has been much discussed for many, many years, and as long as the accountants choose to categorize costs between direct and overhead, overhead control will continue to be discussed.

In years gone by — and even to too great a degree today — when profits sagged, the average company handled the situation almost on a panic basis. How many of you here today have been confronted with an "economy drive" within your own company? How many of you have received some such directive as to cut your costs by 20 per cent within a specified period? How many of you have witnessed, and participated in, a cost reduction program that was directed at the effect rather than the cause? And, finally, how many of you have awakened to the startling discovery that such "economy drives" cost more than they save?

I don't mean to imply that cost reduction does not have a place of prime importance in your organization, and mine. But, when cost reduction ceases to be merely putting out a fire — when it becomes a logical-

ly planned, objective medium to long-term program — when it seeks to cure the cause, rather than to minimize the effect — then cost reduction assumes a new name, and really a new function, which is

PROFIT IMPROVEMENT

Take my own company, Sylvania Electric. At Sylvania, profit improvement is not front office business. It's <u>everybody's</u> business.

It applies to the supervisor as well as the direct labor employee. However, this morning I should like to discuss with you profit improvement as it affects the supervisor of a department, the manager of a plant, division, or even a corporate officer.

When quality goes to pot, shrinkage rises, production falls, sales do not meet the estimates. Then profit, as well as return on investment are substantially lower than had been projected and you ask someone what happened. Two times out of three you may very well get the answer "why ask me, I'm not responsible?" He of course might be right, and if he is, it's because he has not been given the tools with which to assume his responsibility and perform his duties.

Obviously in order for him to be responsible he must know three things:

1. What he is supposed to do.

2. What he is doing.

3. That it is within his personal control to regulate what he is doing.

Here is an example: A plant manager wants to hold a department supervisor responsible for the department's costs. Under the three points that I mentioned above it is essential then that:

a. The supervisor knows what his costs should be according to a budget, a standard cost system, or some similar benchmark.

b. He knows what his costs are. This requires that there be available to him a means by which he can have actual costs reported to him in one form or another on a current basis.

c. He must have control, or he must be able to regulate these costs. This would require that no requisition for materials, assignment of manpower and utilization of services or facilities be authorized except by him or his subordinates if they affected his particular department.

If all of this information is available to him and, by proper description, his job has been reviewed with him, then you are perfectly right in holding him responsible for the fall-off in production or sales, or a rise in shrinkage or a deterioration in quality, and I believe that had he been supplied with all of this information he would have answered your question with some pretty down-to-earth facts with what had happened in his operation during the period under review.

Obviously, it becomes the responsibility of someone in the organiza-

tion to see that this department foreman or supervisor has the information by which he can discharge the responsibilities which have been described to him and with which he is completely familiar. This becomes the responsibility of some overhead employee. Since, then, we are interested in maintaining a minimum amount of overhead, it behooves us to examine methods of assuring that this information is passed along to the responsible person with the minimum of cost involved. We cannot afford to be arbitrary and determine for him what information should be made available to him. Since he has the responsibility for the operation, he also is privileged to indicate to us what he needs in the way of operation, or to put it another way, what tools are required effectively to discharge his responsibility.

Obviously, too we cannot permit each department foreman or each plant manager to obtain different information in different forms and at different times. The cost of preparing special reports for every department manager would be so out of proportion to the benefits to be gained that it could not even be considered. This situation is amplified many times in a divisionally operated company where, by the very nature of the product manufacturing processes, the sales policies, engineering problems and even accounting philosophies, may be somewhat different than apply in other product areas. Accounting and control procedures for assembly operations differ in many companies from the same procedures applied to automatic high speed operations. The industrial engineer is faced with different benchmarks in setting labor standards for performance in a hand assembly operation than benchmarks for a machine operator in a highly automated process. Nonetheless the same basic information must be supplied to the management of all levels in order for them properly to control the operations for which they are responsible.

I have in the past made several talks in connection with Sylvania's approach to integrated data processing. Most of you I am sure are familiar with the company, but for the benefit of the few who may not understand our operations, I think it best to briefly tell you something about the company so that you can appreciate the reason for approach to integrated data processing.

Sylvania Electric is a decentralized company, operating 9 product divisions and one engineering division. We have 48 plants, 18 laboratories, 27 sales offices, and 18 warehouses in 65 communities in 25 states.

About five years ago, in order to take advantage of mechanization, we converted the record keeping from each plant activity to a few area accounting departments. These departments serve plants and divisions on a geographical basis and as a result of the consolidation from plant to geographical area we were able appreciably to reduce the over-all clerical expense and to take advantage of known methods of mechanizing clerical operations.

In our company a basic philosophy is decentralization of responsibility. We believe — and practice — that every decision affecting the operations of the company must be made at the lowest level at which a sound decision — one based on all the facts — can be made.

This philosophy of decentralization has been tried and tested, and is believed by our management to be the best system of management. The benefits of decentralization for instance have increased our sales from $69 million to $311 million in the past ten years. Net earnings during

the same period have increased tenfold to nearly $14 million. We believe, therefore, that this philosophy of management decentralization must be retained regardless of our approach to record keeping.

This is Sylvania's blueprint of integrated data processing. If, at first glance, it appears to contain inconsistency within its structure, I can assure you that no inconsistency actually exists.

First, management required that we retain the philosophy of decentralized responsibility and authority. Secondly, because of our highly diversified product lines reaching a variety of customer groups and market conditions it was necessary that we maintain flexibility of reporting so that the best and most useful information be supplied management in all areas.

Third, some action was absolutely necessary in order to reverse the trend of rising costs in clerical areas at the same time that direct labor costs in our factory units were undergoing a substantial decline because of automation and improved methods. As you probably know, today there are approximately 16 clerks for every 100 manufacturing employees. Based on past history, an extension of the increase in clerical employees as compared with manufacturing employees would indicate that within the next 15 years we might require as many as 24 clerks for every 100 manufacturing employees -- or roughly 1 clerk for every 4 factory workers. Aside from the fact that industry could not afford this ratio, I do not believe that we would have available to us, 15 years hence, the number of people required to maintain the records for the expanded economy unless we change our way of doing things.

Early in our feasibility studies, it became evident that the volume of clerical effort involved in supplying the necessary operating people was sufficient in volume to make the application of a high speed computer practical. At the same time, however, we recognized the impracticality of continuing our area, or geographic, accounting which would necessitate the installation of more than one high speed computer.

Our preliminary surveys also indicated that in many instances we were not adequately supplying the information by which a person responsible for an operation could best control his operation. Some of our operating managers were spending their own time in the compilation of operating statistics -- time which could be much more profitably spent in making operating decisions based on information which had been properly and promptly supplied to them. It became evident that one of our major tasks was to eliminate the drudgery of the supervisor's work, thus allowing him more time for constructive thinking.

Since we could not afford to maintain our area accounting departments and still assume the drudgery of operating management's job, it was necessary that we centralize our record keeping. Our problem, therefore, became one of communications. All of our locations would have to be tied together so as to provide a rapid method of passing information from one to the other. The communications network had to be able to handle administrative traffic, as well as accounting and statistical sales data and operating information. The communications network had to be designed so that these two types of traffic would not interfere with the other. As most of you know, we were successful in working with Western Union, which designed special equipment to provide a communications network which met these requirements. This network is now in operation in our new Data

Processing Center in Camillus, New York, a village just west of Syracuse.

As some of you have probably read, we felt that it was necessary to locate our Data Processing, or Service, Center in an area where we had no other activity, because the Center would service the entire company. We could not risk even a suspicion that the data processing activity was influenced by one or more operating divisions.

The communications network was placed in operation in May, 1956, and I can assure you today that the savings which have developed in other communications areas are more than paying for the communications network on a going basis. Essentially, then the network is paying for itself through the administrative traffic as a result of lower communications costs in other areas, and we are getting a hayride for the data processing function.

Before I describe for you the details of our communications network and the manner in which it ties into the over-all data processing function, I will take a few minutes to give you a status report on the utilization of our Univac equipment.

The Univac was turned over to us by Sperry-Rand Corporation in September, 1956, and our approach since that date has been to utilize the equipment for the clerical efforts where a maximum savings in clerical dollars (people) can be obtained. Accordingly, the first major project was to convert the payrolls for the entire 27,000 Sylvania employees from their area accounting departments to Camillus. I am pleased to say that by July 31, 1957 we should have accomplished this task and will be computing the payrolls from gross hours to net pay, summarizing all of the payroll deductions, and preparing the various federal and state reports regarding withholdings for FICA and income taxes. Because of the different bases for payment to various categories of employees it was necessary for us in order to streamline our payroll to find <u>one</u> common denominator, which we have determined to be <u>payable</u> hours. The payrolls are then handled on an exception basis. All permanent information is retained at the Data Processing Center in connection with each employee and is adjusted only as the employee receives an adjustment in rate or changes a withholding exemption certificate, etc. All employees are considered to work the normal 40 hours, or 48-hour week as the case may be, and payrolls are computed on this basis unless an exception is made for an individual employee, which exception is reported to us by the plant in the form of payable hours.

We did not hold up the conversion of payrolls from present methods which, in most cases, are the usual IBM punchcard methods, to Univac in areas where incentive computations were necessary. Rather, we chose to transfer the payroll to Camillus from a gross earnings to net pay basis and then on a second go-round, pick up the incentive computations in the plants and areas where such computation was applicable.

Following my original theme, however, we are now in a position in most of our plants to supply rapidly to each department foreman the tools which he needs to perform his job in connection with labor costs so that he is in a position to aggressively maintain a minimum labor cost and as a result improve profits in his area. The procedures have been so established that it doesn't make any difference to our service department in Camillus whether the department foreman requires his labor cost breakdown by job, department, cost center, or by type of product. He automatically receives these statistics as required and spends his valuable time in

analyzing the information and in establishing policies which will minimize labor costs. Likewise, such information can be summarized for each plant and for all of the plants in a single operating division where profit responsibility is also assigned to one operating vice president or general manager.

Sylvania's approach, therefore, has been one of eliminating the drudgery from payroll preparation and labor distribution and maintaining sufficient flexibility to be able to give the operating manager his labor costs in a manner in which he requires them for most efficient operations.

Following the same philosophy, Sylvania's second major project combining integrated data processing and electronic data processing is the system of customer order acknowledgment, invoicing and combining the source data for sales statistics, inventory control reports, market analysis and research information, and accounting entries affecting accounts receivable, sales, etc.

A clerk in the district sales office or warehouse using pre-punched tabulating cards will automatically originate a five-channel tape at the time that the shipped documents are prepared and the customer order is acknowledged. These cards will contain all significant details for invoicing and the sequential development of detailed and source data for the operating departments.

Here again our approach has been to provide the basic information required by marketing management, as well as the individual field salesmen and including various merchandising groups, the market research group, the cost accountants and credit departments interested in information concerning the customer's orders, its shipment, subsequent invoicing, and the collection of the accounts receivable.

The information, although maintaining a certain degree of uniformity, is not identical in all respects. The reports have been designed with the cooperation of the respective recipient of the information so as to insure supplying him with the basic tools by which he best can improve his volume and profit position.

In both of these applications the fact that the information is gathered by a central Data Processing Center does not in any way conflict with the philosophy of decentralized management in the company, since the data processing center acts merely as a service department supplying the information to those persons who can use it in the form best suitable for their use. The Data Processing Center has no other responsibilities except this service department responsibility.

I indicated to you earlier that in order for Sylvania to avail itself of the high speed electronic data processing equipment, it must centralize much of the record keeping or service department responsibilities and tie in the outlying sections of the company to the center by a communications network. Our preliminary studies indicated that certain requirements of any communications system were common to both data processing and administrative traffic transmissions. No single commercially available system appeared adequate, consequently, a system was designed specifically for our application by the Western Union Company.

It was recognized that both data processing and administrative

traffic volume would increase materially as the program moved from one phase to another. This system accordingly had to be engineered so that modifications and revisions could be achieved with a minimum of effort and investment.

It was also necessary to build into the communications network an ability to expedite the transmission of administrative messages, and eliminate the necessity for the complete run-out of a large mass of data being transmitted for use at the data processing center. Accordingly, the system was designed with an automatic routing and classification device which scans incoming circuits, immediately classifies information according to its function, and switches the sorted data cross-office on a high speed basis to one of several reperforator positions.

The equipment is flexible so that on a day when a high volume of payroll information is being transferred, most of the reperforator positions can be assigned to accumulate payroll information. Likewise, other peak load operations can be handled on a selected basis.

The system was designed so that a minimum amount of decision making would be required at reporting locations. I am sure you can appreciate that with more than 70 locations reporting, we could not risk misinterpretation of instructions by 72 individuals and still maintain consistency. Accordingly, a selector on the communications machine which is basically of the sequential device monitors, the circuit for the operator and makes the decision when to commence and when to stop transmission. Under the present operating procedures the communications operator does not necessarily have to differentiate between computer traffic and administrative traffic. She merely inserts the tape in the transmitter gate, hits the circuit request button, and then tends to some other duty: the selector has the responsibility of picking the circuit up and starting the transmission at the proper time. The data control system will properly discriminate between computer traffic and administrative traffic and assign the respective types of information to a reperforator position.

FUTURE PLANS

The installation of a complete electronic data processing system requires a considerable amount of planning and programming. It is much more complicated in its programming requirements than the punchcard equipment with which we are all familiar, and, consequently, the time cycle between the concept of a data processing procedure and its satisfactory operation is greater than any of us have been accustomed to. We are satisfied in my company that the program is sound and that the cost savings which we estimated would accrue will be attained and probably exceeded. Our approach, however, will still be a methodical, well-planned, and carefully executed transfer of the processing of information from our present methods to the Data Processing Center.

The approach, however, will be consistent with what has taken place to date — that of supplying basic information to all levels of management to assure the best possible tools at the lowest possible cost and to maintain low overheads by a positive profit improvement concept.

For example, accounts payable will be centralized, not only so that cash may be utilized, but so that unless all material efficiencies, factory supplies usage, overhead expense breakdowns, etc., can be determined

by department, by plant, to all divisions or product lines in an effort to supply all management levels with comparative information by which they can best judge the efficiency of any particular part of the company.

Here again, the aim is to obtain rapid information for management so as to improve our profit position.

In summary then, we must recognize that industry generally is faced with lower margins between cost and selling price. I believe that these margins will continue to shrink and that efficient operation is the only thing that will assure a reasonable profit margin. Accordingly, then, it is necessary that cost saving methods be developed for clerical as well as factory operations.

Secondly, because of the highly competitive situation in most industries and, particularly in the electrical-electronics industry, it is necessary in order to remain in a reasonable profit position to obtain more and better information about your day-to-day operations, and see that the information is properly channelled to the management personnel who can do something about a bad situation.

Thirdly, if it appears economical to obtain this information for all levels of management through a central source — so long as the central department is recognized strictly as a service department to gather, interpret, and present operating information to responsible management — it does not in any way reduce the effectiveness of a decentralized management program.

All of these are, in the opinion of our company, positive ways of reducing or minimizing costs and increasing or improving profits.

THE INDUSTRIAL ENGINEER AS AN AID TO TOP MANAGEMENT

Hal E. Nourse
United Air Lines, Inc.

Introductory

Thank you, Matt Payne, thank you very much indeed for that fine introduction. A finer one would be hard to come by regarding your speaker of the moment.

At the outset let me say this speaker would be less than honest if he were to pose before you today as an expert in Industrial Engineering, an expert in the detail of engineering technique. This he is not. Rather, he would like to pose as one who has had considerable experience near the top level of management and in the area of management planning and control; enough experience, so to speak, to have formulated certain ideas on the philosophies, objectives and organization for industrial engineering when used as an effective tool for top management.

Before we get within the hard core of the remarks today, it is enough to say that the best procedure would be to propose a little philosophy, a little food for thought as it were, and then tell a simple, straightforward case history of the company that furnishes a certain Hal Nourse and family with "bread and butter" regularly, and that company's intimate acquaintance with industrial engineering. You should be interested in that "bread and butter" routine, whether it is food for thought or to eat. In this case history it will be one objective to establish several reference points to the earlier stated objectives and philosophy.

Philosophy

Last November your Long Range Planning Committee held a meeting at Purdue University at which it accepted a definition of Industrial Engineering. The summary of this symposium makes very worthwhile reading, and is commended to your attention. Believe me, today it is not trite to get a definition before you immediately because it establishes at the outset the key formula of the remarks to follow. This formula is three-dimensional and anything three-dimensional has breadth and depth. If you will look on the proper page of Noah Webster's masterpiece, you will find in bold type this masterful sentence: "INDUSTRIAL ENGINEERING IS THE TECHNIQUE OF ORGANIZING AND CONDUCTING AN INDUSTRY OR ENTERPRISE." How long ago this definition was written is not known; it was found by your speaker in the 1936 unabridged edition of the book. This "oldish" definition was chosen deliberately over the very fine definition of your long range committee to illustrate a point: Has the fraternity been missing a bet as to its real significance to top management?

Last year in Los Angeles there was a regional AIIE meeting and there were a few "cracks" about the time study board and stop watch, together with some banter back and forth about low engineering wage scales. This is not good. In more and more circles the status of the industrial engineer has attached to it the connotation of management. Top management, if you will. There are no doubt many in the fraternity who still cling to that "stop watch" philosophy, your speaker is not one.

There seems to be a number of requisite qualifications one must aspire to if he is to adopt and practice the broader concept of Industrial

Engineering. Here are a few of the more important.

First, and it is so obvious one hesitates to mention it, he must be a good technician. He must of course know his trade. Whether he be working in the financial, distribution, production, or other areas of management, he must know what tool to select, and like the surgeon - on occasion there are variable choices. He must be exacting on such occasions as much may depend upon that selection.

Second, and far less obvious, he must be not only an engineer as such, but also a human engineer - one who can practice "political humility". Now that is a new twist, isn't it, whether it is a good or bad phrase is immaterial to the thought behind it, which, incidentally, is not the practice of deceit but rather the practice of psychology to help gain a work objective. Tools or no tools, how else can one gain one's objectives. Putting it another way, he works in the area of service to others, to management, if you will, and as such he must learn the delicate art of being superior to his client but giving the opposite impression. He must be willing to pass on the glory and the credit at the moment for the longer range gains. This is extremely difficult for some of us. If we get a good idea today we usually want the world to know it yesterday.

Human Engineering vs. Technical Engineering. These are the twin pedestals upon which my company has striven to build a purposeful and objective engineering operation. These pedestals stand of equal strength and height, but far enough apart to collapse the main structure if either is removed - the objective will not succeed one without the other.

Third, and lest you may be anticipating what will come next, we hasten to add there are other requisites to success in industrial engineering, such attributes as the ability to think - think creatively. It can be developed, you know. There is the matter of judgment backed with extensive facts and common sense, the matter of character, etc. All of these requisites must be present in the twin-pedestal approach. All of course can be closely linked with the success story not only in the area for discussion today but throughout the entire area of management. Let us be content, then, to leave the emphasis on the twin-pedestal approach and go on to the next - "Kernel for Thought".

Fourth, and did you ever stop to realize there are at least two interpretations that can be placed on that familiar phrase - "the authority of ideas". The interpretation heard most frequent is that which links it with the functional organization in which the staff gets the idea and the line organization produces the action. Perhaps a more selfish interpretation, an interpretation which will help to build the stature of the industrial engineering organization, is as follows: If one becomes interested and becomes an expert in a useful field, whether it be innovation or known, soon management will gravitate toward this individual seeking his help in such areas. With the passing of time he becomes the authority with definite responsibility attached. Here is an illustration of what is meant.

There is a man in this country who got the simple idea that a national sampling survey of industry periodically on a certain major component of our economy would be a useful planning tool for industry in general. He went ahead and now after a number of such surveys he is the recognized expert in this field and has become an economist of national

reputation.

There is little doubt but what this acceptance and authority has resulted in great material gains for this individual, including a top job in his field.

Two or three of the components now embraced by the industrial engineering area in this speaker's organization were established through the progressive pursuit of an idea for service which no one else had thought of. Today the idea has deep-rooted authority and responsibility attached to it.

Fifth, and moving a little different hue or color over the spot on this same philosophy, it should be remembered that many times top management without help moves in an area of frustration. It, of course, organizes itself to cut down this frustration but men with the training and talents of the industrial engineer are a natural to provide this help. Without expressive action, management as a rule is in the dark as to what industrial engineering can do for it. It takes initiative and a steady record of results before the full potential of industrial engineering is realized.

Just another facet of this idea. One of the most important things an industrial engineering function can bring to management is a down-to-earth and organized approach to problem-solving. This becomes doubly important when the group is protected by its position on the organization chart so that it can bring real objectivity to each assignment.

Sixth, as the corporation grows the industrial engineering function serving top management must realize it cannot retain all the technical routine functions which may have been its starting point when the corporation and its complexity was much smaller. This detail work of yesteryear must be passed on to the line organization to free up time for the broader and higher level problems. It is only through this process that the department can multiply its effectiveness through others. Many times this idea of giving something up that has been done in the past is a hard lesson to learn. Some never learn it - some never progress.

Another difficult thing to get across to the engineer is the fact that his presentations to management should be through its mind and eyes not through his own with its technical background. Believe me, there is a difference!

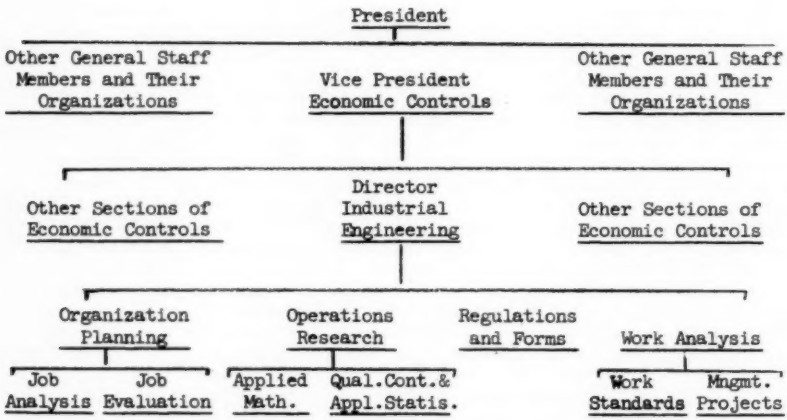
Seventh, if your industrial engineering organization has gained respect and acceptance your services will be sought at the several levels of management. This can pose a problem because it can take the emphasis off the needs and service to top management. If you would keep this top management's favor, adopt the policy of priorities of assignment starting with the president of your corporation. Adopt the philosophy that any assignment from the top in the long run must be best for the corporation, and, needless to say, best for you.

Eighth, in a large corporation the industrial engineering function cannot hope to accomplish within itself its many goals. The function properly placed on the over-all operation chart, a place of independent status, has a real opportunity to train others to help keep faith with an over-all objective. An opportunity to train the staffs of the line organizations in a number of operating and business techniques and engineer-

ing situations. As a matter of fact, in United Air Lines some areas of the industrial engineering function does nothing but sponsor programs and train the line staffs to carry them out.

Organization

Reference has been made about the strategic placement of industrial engineering in the company organization structure if the function is to operate on a broad basis and become an effective tool for high level management. This has been the objective of the Industrial Engineering function of the company your speaker represents. To help attain this objective, it has been placed in the company organization apart from all the operating divisions. Instead it answers to a vice president who also has a number of top level coordinations and planning functions, including industrial engineering. This vice president is on the company's general staff and answers direct to the president. The industrial engineering function, then, has a clear and unobstructed channel to the chief executive through its immediate supervisor. It gets its assignments either direct from the president or a vice president. The tollowing chart will illustrate this strategic placement which is located physically in Chicago, except that the "Work Analysis" section is repeated in Denver, Colorado, to serve the Operating Base and in San Francisco to serve the Aeronautical Engineering and maintenance of fleet base.



It is not the purpose to convey the thought that all work of industrial engineering nature is done by the central staff just referred to. Rather, this group develops and sponsors company programs, trains line technicians, coordinates company team efforts, works on special assignments having to do with policy formation, and acts as an internal consulting agency to the general staff of the company. It is estimated that about one-half of the physical and mental effort in these areas is provided by the central group - and most of its effort is one of motivation and planning. The central group, however, is the only place in the company where the title of Industrial Engineer is used. Those who work with this group from the other departments of the company carry staff titles

even though some of them may have formal industrial engineering degrees, and may even have been transferred from the central group at some previous time.

The matter of training others in the field of specialized engineering techniques has been touched upon. It is worthwhile also to mention another training aspect. That of training young industrial engineers for responsible line jobs or jobs in other areas of the company. It is your speaker's opinion that it would be difficult to find a better spot for a young man to get a quicker grasp of the over-all business and operational facets of the air transportation business than in the centralized industrial engineering section. The operating vice presidents have been alert to this situation since the engineers with their project and team work become very visible to the right operating people. Proof of this is the simple fact that over two dozen of the central engineering staff have been transferred to other part of the company in a short span of years. The great majority of these transfers have represented promotions. This movement and rotation is good as long as the transferees can be replaced at the bottom with equal potential - even if not in maturity and development. Time will care for the latter.

About one-half of the personnel of the company are now under a work standards control program. The company's Job Analysis and Job Evaluation and Organization Planning function just passed its 14th birthday, and the program is now mature.

The Regulations and Forms organization is a coordinating, editing and monitoring agency. It has paid for itself on a hard cash basis many times with its monitoring and printing standards. As one would guess, the Applied Mathematics and Statistics section is the baby of Industrial Engineering in United. Even so, it is already walking forward at a brisk pace. Case study number five to follow will illustrate one area of work for this small group.

Case Histories

During the last several minutes certain basic philosophies and concepts have been reviewed. Now comes five case histories in United to indicate the manner in which these concepts are carried out in actual practice.

Case History #1: STATION MODEL

The objective of this project was to profide a means of simulating real life at a station, so that the operation could be optimized in terms of service, effectiveness, and cost.

All necessary data pertaining to the operation were obtained. These data included flight arrivals and departures, airplane turnaround times, line maintenance dock and gate facilities, availability of men and materials, and other vital information. In other words, all factors that have a bearing on the reliability of a station operation under a given schedule pattern.

The use of this model enables the simulation of 100 days of actual operation at a station in just 12 minutes! This simulation device enables management to test - in advance - policy decisions affecting manpower, facilities, schedules, and costs. The programming of this project on an

IBM 704 electronic computer was a problem of great magniture and it took months to complete.

Referring back to concepts, Industrial Engineering contributed creative thinking, imagination, and an organized approach to the problem. It is your speaker's opinion that the company's management is to be commended for its willingness to gamble 18 months time and considerable money to test this new approach in solving a problem. Although the gamble is still on, we now have positive hopes it is going to pay off.

Now that the model is operative, the role of industrial engineering today is a matter of training the proper operating people so that the model may be used correctly. Posing the right type of question to the model results in answers that should save the company much more than the cost of the study, while at the same time maintaining or improving the level of service to the customer.

The matter of team effort has been mentioned. The station model study is an excellent example of the manner in which industrial engineering coordinates and motivates team effort. This study was undertaken by a team coordinated and led by a senior industrial engineer. The team had qualified members of the interested operating departments, and here is the way it was set up:

One Industrial Engineer - Coordinator
One Aeronautical Engineer
One Ground Services Technician
One Passenger Service Staff Man
One Dispatch Supervisor
One Outside Expert, on occasion

There was a steering committee of using general staff officers which the working group conferred with when policy guidance was needed.

This team approach coordinated by industrial engineering has been very popular in United Air Lines. Air transportation is a functional proposition and a number of the operating functions overlap one major department with another. In other words, one operating group may make decisions or adopt policy that effect other independent groups. Since this is the nature of the business, the line or operating organizations prefer a coordinator with no selfish operating motive, no axe to grind except that of an economic objective. This is simply stating another advantage with respect to strategic placement of industrial engineering on the over-all organization chart.

Case History #2: RE-ORGANIZATION OF RESERVATIONS DEPARTMENT

A few months ago, the Industrial Engineering Department was asked by the President to perform an organization review of United's Reservations Department. For your information, the size and complexity of the field offices had increased substantially in recent years, with little change in organization structure. The study was motivated by customer reaction and possible loss of revenue.

Review was made of the headquarter's staff, functions performed by the field offices, and related functions in other departments. The unique position of industrial engineering in the organization reporting directly to the president made it relatively easy to objectively review the needs

from an over-all company viewpoint. At the same time, working with the operating officers concerned.

Also, realignment of responsibilities was made at headquarters, recognizing the importance of the function from a public attitude point of view. Another related function, which formerly reported to another operating officer, was also brought in to make a complete managerial package.

In this case history, the planning role of the Industrial Engineering Department was important in tying together objectively all of the facets of this organization problem from an over-all company standpoint. Also, this illustration points out the current status of Industrial Engineering with broad and policy-type assignments being given and accepted.

Case History #3: LONG RANGE SPACE UTILIZATION STUDY

This case history concerns itself with the development of a systems engineering concept to assure maximum utilization of available seats through 1967. In other words, it is a long range look at the problem of space utilization.

Many of you are aware of the problems that the airlines are having today in the control of reservations. To those of us in the airline business, the problem of accounting for reservations has been growing for many years.

Our approach to this study used the team concept again, with an Industrial Engineer serving as chairman. Leadership in this area involved the twin-pedestal characteristics of technical training in approaching an electronic problem as well as the ability to work with people, and thereby assure acceptance of findings and results.

After some ten months of exhaustive searching into space control requirements, a basic use specification was published. This specification outlined United's needs through 1967 in terms of creative, innovative concepts in systems design engineering.

Through the ground work and approach of the team, management endorsed the use specification as a blueprint for the future, and their approval was readily forthcoming when the retention of an outside technical consulting firm was requested. The role of this consultant was to evaluate objectively the equipment of all manufacturers in the field. This evaluation was for the purpose of determining operational characteristics of equipment in relation to the use specification. Also involved was the translation of the use specification into technical, electronic requirements.

Again, the organizational placement of Industrial Engineering has been of prime importance in crystallizing long range space utilization needs on a companywide basis.

Case History #4: COUNTER CONGESTION STUDY

An extremely interesting project completed sometime ago was an analysis to determine the number and type of counters needed in the passenger lobby at the Chicago Terminal.

No doubt many of you have experienced difficulty and waited in line in order to reach a baggage or ticket counter. United's desire in this study was to optimize the number and type of counters in order to achieve the lowest waiting time per passenger.

In this study it was essential to view the problem through the eyes of the operating departments. After all, they had the responsibility of setting up the counters initially, and any suggestions that might result in change should be presented with full awareness of their frames of reference, or, if you will, the political situation.

As you can appreciate, this study required certain basic data on arrival rates of passengers during peak periods of the day, as well as data on processing times.

After all basic information had been obtained, the next step was to program the problem for a computer. In this case, after the logic program had been developed, outside consulting services were hired so that the program could be translated into machine language.

The approach to the solution of this problem was a broad one. It was felt that rather than learning the technique of machine translation, Industrial Engineering's role should be that of organizing the problem, obtaining certain parts of the answer from someone else, and then integrating all data into an acceptable solution. In other words, we deliberately tossed away smaller responsibilities in order to pick up larger ones.

After all input tables had been developed and the nature of output tables determined, we ran the problem on a computer. The results were excellent. The general manager of the operating department concerned readily approved the recommendations, and the existing counter configuration was changed. It is now planned to apply the findings at other major stations.

Case History #5: INDUCTIVE ACCOUNTING

This illustration refers to the new forward look in accounting, called Inductive Accounting. This forward look is based on the technique of statistical sampling. This technique, which has made quality control such a widely accepted and used tool, has now invaded the accounting fields.

In this area, United has been working with certain other major airlines. Industrial Engineering contributed the authority of ideas, and agreement has been achieved on the use of this new accounting method. Through Inductive Accounting, certain carriers are now settling their interline accounts, using sample data to estimate settlements. These estimates are accurate within one-tenth of one per cent for cumulative six-month periods, and require a sample of only five to ten per cent of interline tickets. Accuracy requirements of accounting management are satisfied, and there is a very substantial saving in clerical manpower. A typical settlement for one month would involve some 15,000 tickets, involving a value of one-half million dollars with 1,500 of the total tickets sampled.

Thus, using the authority of ideas and an organized approach to problem-solving, Industrial Engineering has made a contribution to acceptance

of Inductive Accounting in the air transportation industry.

Summary

You, no doubt, have noticed the similarity of certain threads that run through the cloth of each of these case histories. These threads constitute the basic philosophies and concepts used in United in making the services of Industrial Engineering available and meaningful to top management. If these principles were to be summarized, they might be as follows:

1. The placement of the Industrial Engineering function in an organization must be such as to encourage and stimulate objectivity and new ideas. In no sense can the placement be a barrier to interdepartmental thinking or system concepts.

2. Industrial Engineering must take its proper place as an aid in policy formation for top management. It must be more than time study.

3. An organized approach to problem-solving is one of the very real talents and contributions that Industrial Engineering can make to an organization. It must be encouraged and developed.

4. Creative ability must be present and must be developed through pioneering efforts. Industrial Engineering must think big in order to assist in top management decision-making.

5. The authority of ideas must be demonstrated through actual, practical installations that serve the needs of the operating organizations.

6. There must be balance in Industrial Engineering between formal technical training and the ability necessary to work with and through other people. These are the twin pedestals forming the foundation of Industrial Engineering.

7. There is a need to be aware of management's attitudes and of political conditions which may exist at some times in an organization. This does NOT mean that one needs to "rise above principle" on occasion or sacrifice integrity. However, it does call for care in approaching a subject and recognizing the practical importance of timing in endeavoring to achieve acceptance.

8. The team approach can be very effective and completely acceptable to the using organizations.

9. The training aspects of properly conceived Industrial Engineering is "double bladed" - one blade having to do with training of others by the engineer, the other having to do with his own training and hence providing opportunity for promotion.

In short, gentlemen, there isn't a management today that isn't looking for some one to help in the development of better systems, measurement devices, better planning and control. Gentlemen, you are just the boys that can do it.

NEW METHODS AND APPROACHES IN WORK MEASUREMENT

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At present, work measurement is based on time study, predetermined "motion-times" and standard data. There is no doubt that these methods have been and still are very useful. In most instances the energy expenditure necessary to accomplish a task is not measured, which leaves the assessment of human effort up to the judgment of an observer. Consequently inconsistencies and errors can occur; and even though progress has been achieved, one should not take for granted that a satisfactory solution to the problem of human utilization in industry has been found.

Work and rest standards as they are now established are more or less arbitrary. They do not take into account the efficiency and the power of the worker's muscles, heart and lungs; they do not necessarily represent the time needed to perform an operation with a minimum physiological cost and a maximum efficiency of production; they represent even less the time needed to insure an adequate recovery between successive operations. The "physiological cost" of jobs should be measured because it is the only accurate means of determining human effort and it should be kept within safe limits. This is an essential factor in job organization, in job evaluation, in the selection of workers and, as a consequence, in labor-management relations.

Numerous experiments have been performed to study the physiological effects of muscular work of varying degrees of intensity. It is known that, when shifting from a resting condition to one of physical activity, many physiological functions change from their "resting level" to a "working level". Heart rate, blood pressure, cardiac output, pulmonary ventilation, oxygen consumption, chemical composition of the blood and urine, body temperature, and rate of sweating are all modified by muscular activity.

By measuring one or more of these variables during activity it is possible to determine by how much the "working level" differs from the "resting level". This gives an estimate of the degree of physiological stress experienced in performing a given task. After activity ceases it is possible to follow the return of these variables to the "resting level" and to determine the duration of the "recovery period" at the end of which the individual is back to the preactivity physiological equilibrium. In order to evaluate the physiological expenditures involved in a given job one has to take into account not only the physiological reactions during work but also those during the recovery period. In other words, from the human point of view, a complete "work cycle"

includes the physiological cost of work plus the physiological cost of recovery since, when mechanical work stops, physiological work continues above the resting level until recovery is completed.

The question now arises: What physiological reactions should be used in work measurement? The determination of oxygen consumption and/or heart rate changes are the most reliable and the most practical methods. All muscular activity requires the consumption of oxygen above the resting level. This additional oxygen requirement is proportional to the intensity of work per unit of time and to the duration of work. Energy expenditure for any specific activity over a definite period of time can thus be calculated and is expressed as oxygen consumed or as kilocalories per minute. This technique has been used extensively and the average energy expenditure has been measured for a great number of industrial operations. Tables have been computed which permit one to estimate daily energy expenditure. With the help of few metabolic measurements, these estimates can be accurate within 10 per cent (1). In spite of its usefulness this method has several drawbacks in practical industrial applications. The equipment is rather clumsy and uncomfortable to wear; the number of workers that can be studied in a given situation is limited because the apparatus is expensive and the procedure is time consuming; it requires qualified technicians to collect and analyze the samples of expired air from which the oxygen consumption is calculated. Furthermore, additional factors of physiological stress, such as heat and clothing, cannot be evaluated by oxygen consumption alone. The result is that, in many industrial operations, measuring oxygen consumption gives only a partial picture of the total physiological cost.

On the other hand, heart rate values during work and during recovery from work are now recognized as being an accurate means of evaluating physiological cost. The heavier the load, the greater the energy expenditure and the faster the heart rate (2, 3, 4). During exercise "the pulse curve alone quite accurately depicts the physical state" (3). It has also been shown that the behavior of the pulse rate after muscular exertion depends on the work load and the duration of effort (5). For a constant duration of activity, the greater the work load per unit of time the longer will be the recovery to the resting heart rate. For a constant work load per unit of time, the longer the duration of muscular activity the longer will be the recovery of the heart rate to its resting level.

In addition the heart rate is influenced by the heat dissipating mechanisms of the body, and it varies during work and during recovery according to the environment in which the work is done and to the clothing worn by the worker. Consequently the working level of the heart rate is determined by the work load, the environment in which the work is done and the physical capacity of the individual. The heart rate recovery to the resting level also depends

upon these various factors and is proportional to the stress experienced during work. By measuring the time it takes to recover from work, a situation leading to physical fatigue can be evaluated.

A man who cannot recover to a satisfactory level between work cycles will present increasingly higher physiological reactions as more work cycles are performed and fatigue will develop as the shift progresses. If fatigue is not too severe, it will completely disappear during the interval between two shifts and the man will report to work with a normal resting level of physiological reactions. If the work load is greater, the interval between shifts may not be long enough to insure complete recovery and accumulated fatigue over days, weeks or months may occur. It is, therefore, essential to evaluate with reasonable accuracy the recovery time or "physiological rest allowance" for industrial operations. The work time can be accurately assessed by a stop watch, but without physiological measurements the recovery time cannot be determined.

If the physiological cost of a given job in a given environment is to be estimated, the reactions of the workers doing the job must be studied. Not only the average reactions but also the range of reactions must be determined in order to obtain precise information.

The variability of human adjustment to a standard stress situation is seldom appreciated and can be illustrated by the following example. Students at Harvard College were given a physical fitness test known as the "Harvard Step Test" (6). Over two thousand healthy students participated in the experiment. This group included men of low physical efficiency as well as varsity athletes in excellent condition. It was found that the capacity to withstand the stress of hard muscular work was ten times as great in the fit as in the unfit (7).

Even in a more restricted and highly selected group of varsity and junior varsity trained athletes, the best men were able to perform hard physical work twice as efficiently as their less fit colleagues. These results emphasize, quantitatively, the well-known fact that men vary markedly as far as their physical capacity is concerned; and that, even in trained and selected groups, wide variations are found in the physiological price that individuals have to pay to accomplish a given task.

The physical capacity of the individual is the result of numerous factors such as the innate potential of physiological mechanisms, age, health and nutritional status, sex, specific fitness for a given job and for given environmental conditions. These factors exist in any industrial population, and similar differences have been found among workers (8).

Considering the range of individual differences that may occur in the same industrial situation, it is obvious that

the usual techniques of work measurement are unable to evaluate, even grossly, the physiological cost of a given job. It is also obvious that no observer, regardless of how competent he is, will be able to formulate a sound and quantitative estimate of human effort by using judgment alone. The lack of precise knowledge about the workers' physiological reactions to the job is probably the most fundamental criticism that can be applied to the classic methods of work measurement.

Several experiments will now be discussed which show the importance of assessing the physiological factors in work measurement.

1. Subjects were pedalling a bicycle ergometer against a known load in a room where the temperature and humidity were strictly controlled. Among other variables heart rate and oxygen consumption were recorded continuously before, during and after exercise. During the first thirty minutes of exercise the work load was 540 kilogram-meters per minute. Then the load was increased to 900 kilogram-meters per minute for four minutes. After the end of exercise the recovery processes were followed for sixty-five minutes. These experiments were performed under two different environmental conditions; namely, 72° F and 50 per cent relative humidity and 90° F and 82 per cent relative humidity. Figure 1 presents the average curves calculated for six different male subjects. It shows the immediate increase in heart rate and oxygen consumption which takes place as exercise begins. As the moderate work at low temperature progresses there is a slight increase of the heart rate, but the oxygen consumption remains at a steady level. As soon as the work load becomes heavier, heart rate and oxygen consumption increase immediately and keep increasing until the end of exercise. During the recovery period the oxygen consumption is back to the resting pre-exercise level after twenty-five minutes; the heart rate diminishes less rapidly and is still well above the resting level after sixty-five minutes of recovery.

   When the experiments are repeated at higher temperature and humidity, the heart rate increases definitely more than at lower temperature both during moderate and heavy exercise. It also remains at a higher level throughout the recovery period. On the other hand, the changes in oxygen consumption are similar to those observed at the lower temperature and the slight difference between the two curves is not significant either during exercise or during the recovery period.

   In addition to the well-known fact that heart rate and oxygen consumption vary with the work load,

these experiments show that oxygen consumption was not affected by the environmental conditions in which the exercise was performed. On the other hand, heart rate was definitely higher when the stress produced by a warmer and more humid environment was greater, and therefore it appears to be a more faithful index of physiological cost.

In such experiments it is obvious that the usual methods of work measurement could not accurately evaluate the strain produced by the work loads and by the environments nor the physiological cost and the time it takes to recover after work.

2. The influence of repeated work cycles and of increasing dry bulb temperature is illustrated by the following experiment.

Subjects wearing shorts were pedalling a bicycle ergometer against a standard work load. The heart rate was recorded continuously. The test consisted in working for five minutes, waiting long enough for the subject to recover to a heart rate of 110 beats per minute and then performing another five-minute work period. In this experiment the "rest allowance" between two successive work cycles was not determined, as usual, by the stop watch but by a physiological reaction; namely, the time necessary to return to a heart rate of 110 beats per minute.

A total of ten successive work periods was performed, keeping the humidity constant at a relative humidity of 50 per cent and with a dry bulb temperature of 72° F and 100° F respectively. Figure 2 gives the average heart rate curves obtained under these two environmental conditions. The heart rate during work is definitely faster and the recovery time longer when the temperature is higher. For performing the same total amount of work and recovering to the same physiological level after each work period, it takes about fifty-five minutes at 72° F and seventy-seven minutes at 100° F. When the recovery times alone are compared, their total is 5.5 minutes at 72° F and 27.3 minutes at 100° F. In industrial situations where similar factors are involved no work measurement based on time study alone would be sufficient either to estimate the difference in physiological strain or to adjust adequately the rest allowances when the temperature in the shop varies from 72° F to 100° F.

3. When humidity increases, evaporative cooling decreases rapidly, thus reducing the ability of the body to dissipate heat. Under these conditions high heart rates, high body temperatures, and very slow recovery after work result in pronounced fatigue.

Changes in heart rate were observed before, during and after a standard amount of work at various temperatures and humidity. For the higher range of temperature and humidity the recovery from work was shown to be incomplete and to remain so for as long as thirty minutes after the end of work. Complete recovery is impossible when the surrounding atmosphere is too warm and too humid, and fatigue appears rapidly under such conditions (see Figure 3). Here again physiological data are needed in order to evaluate properly the additional stress produced by high humidity.

4. The additional stress produced by wearing a special kind of protective clothing was also studied. The subject performed two ten-minute periods of work at 360 and 540 kilogram-meters per minute, respectively, separated by a fifteen-minute rest period. Various environmental conditions were used and two tests were run under each of them. In the first the subject wore only shorts and in the second he wore the protective outfit. Heart rate was recorded continuously during work and during the recovery periods. Figure 4 compares the results that were obtained at the two extreme environmental conditions tested with and without the protective clothing. The lightly shaded areas between the two lower curves represent the stress added by the clothing at 72° F dry bulb and 64 per cent relative humidity for the two grades of work. One can see that, during the second exercise period with a heavier load, the difference in heart rate observed with the two types of clothing became definitely greater than during light exercise. The heart rate recovery was definitely slower when the protective outfit was worn. The darkly shaded areas between the two upper curves show the same phenomenon under the most adverse environmental conditions explored in this research; namely, 115° F dry bulb and 22 per cent relative humidity. The stress produced by the protective outfit was considerably greater than under less severe conditions and particularly so with the heavier load and during the following recovery period. In addition to the difference in cardiovascular reactions it was also found that body temperature increase and sweat loss were always definitely greater when wearing the protective outfit.

Figure 5 summarizes the results obtained in the preceding experiments when the maximum heart rates observed during work are plotted against temperature. It shows a rectilinear increase in peak heart rates with increasing temperature for light and medium work while wearing shorts or the protective outfit. The slopes are considerably steeper for those experiments in which the outfit

was worn, indicating that the "clothing stress" becomes a more and more important factor in determining the physiological reactions of man working in progressively warmer environments.

Figure 6 shows the relation between temperature and the pulse rates measured during recovery one, two, three, five and ten minutes after cessation of work. These latter are designated by P_1, P_2, P_3, P_5 and P_{10} respectively. It appears that the relation becomes curvilinear and that the recovery processes immediately after work become rapidly slower and more costly as the temperature increases.

These experiments show clearly that physiological measurements are needed in order to evaluate the stress produced by clothing during work and during recovery in various environmental conditions.

5. Physiological measurements are also essential to evaluate the stress reduction obtained by improvements of the working conditions.

The following experiments illustrate this statement. In certain industrial operations in which the workers are exposed to high heat, it is often impossible to improve sufficiently the situation by shielding the sources of heat, increasing the ventilation or cooling the area. Research carried out at Haskell Laboratory led to the development of a permeable ventilated suit and helmet designed principally to protect the workers from extreme heat (9).

A series of tests were made in the Laboratory at 111° F dry bulb and a relative humidity of 67 per cent. Figure 7 summarizes such an experiment. In Section A the subject sat quietly for fifteen minutes. The first exercise period was performed wearing the suit and the helmet. As shown in Section B. the heart rate increased and reached progressively a maximum of 118 beats per minute at the end of that ten-minute period. After fifteen minutes of rest the heart rate was down to 98 beats per minute (Section C). At that time the helmet was removed in order to ascertain the physiological difference between breathing cool dry air and breathing hot humid air. The second part of Section C shows that at rest there was practically no difference in heart rate, but that the body temperature rose from 99.1°F five minutes after the first exercise to 99.8° F five minutes after the helmet was removed, indicating an increased stress on the thermoregulating mechanisms.

During the second exercise the heart rate reached a maximum of 125 beats per minute (Section D). During the recovery period (Section E) the

heart rate went down to 108 beats per minute in fifteen minutes, i.e. 10 beats higher than after the first exercise. Body temperature rose to 100.3° F five minutes after exercise. Higher heart rate during exercise, slower heart rate recovery and higher body temperature indicate that the stress was greater without the helmet than with the helmet.

After fifteen minutes' rest the air ventilating the suit was shut off and the subject, suited but without helmet, was exposed to the environmental conditions of the room. The second part of Section E illustrates the immediate increase in heart rate that occurred while the subject was sitting motionless. From 108 beats per minute the heart rate increased steadily to 130 beats per minute before the start of the third exercise period. Exercise produced a further and very marked increase in heart rate reaching a maximum of 162 beats per minute at the eighth minute of exercise. The work became so uncomfortable that the subject was unable to complete the ten minutes of the regular exercise period (see Section F). The heart rate remained at 150 beats per minute for five minutes after the end of exercise. At that time the body temperature had reached 101.4° F, and the subject, feeling dizzy, was taken out of the hot room.

This experiment showed that with the helmet and the suit ventilated the work could be done easily and the recovery was satisfactory. Removing the helmet and allowing the subject to breathe hot and humid air definitely increased the stress on both the cardiovascular and thermal systems. Eliminating the air supply to the suit increased the stress considerably and made the work so uncomfortable that the test could not be completed.

On the basis of these experiments, the air-conditioned suit was tested in industry. Successful trials were made in various jobs involving manual labor and exposure to extreme heat (9). Figure 8 gives an example of the reduction of heart rate reactions obtained by using the ventilated suit. Here again it is obvious that without physiological measurements no accurate evaluation could be made of the strain experienced by the workers under these various conditions.

From the point of view of work measurement the general conclusion of such experiments is that time studies combined with good judgment will not enable one to evaluate the physiological reactions of the worker to the job when variables such as temperature and clothing enter the picture. Even if the energy expenditure can be assessed within reasonable limits

from existing tables (1), the true physiological cost remains unknown unless physiological measurements are made during the recovery period. A simple method for making such measurements has been previously described (8, 10) and has been successfully used over the last fifteen years to estimate the physiological strain in a number of industrial operations.

The physiological considerations that have been discussed so far in relation to work measurement apply only to work of sufficient intensity and duration to produce reactions that are measurable by the usual physiological techniques. If the work is too short or too light, other methods have to be used. Among them the "force platform", designed by L. Lauru, has proved very valuable in measuring the efforts involved in performing motions (11). These measurements are made through sensing elements which are piezo-electric quartz crystals developing a dielectric polarization when they are compressed. The compression of the quartz crystals is only a few microns and forces from a fraction of an ounce to several tons can be measured. A triangular and very rigid platform permits the location in space of the various quartz crystals so that they can simultaneously pick up force phenomena arising vertically, frontally and transversely. These are amplified and recorded. With the subject on the platform, the whole system is balanced to zero. As soon as the subject moves, the piezo-electric quartz crystals registering in the three dimensions are submitted to pressure variations. The pressure variations are proportional to the forces applied to the body by the neuromuscular system, and these forces are a measure of the effort required to perform a specific work.

Figure 9 shows a record obtained for the three components: vertical, frontal and transverse, when the subject bends the knees, stops and then straightens up to an upright position. It may be seen that bending involves active forces from muscles displacing the body downwards and braking forces from the antagonist muscles which control and finally stop the motion. Straightening up also involves an active effort and a braking effort which produce a typical diphasic curve. During any motion the apparatus continuously and quantitatively records all the dynamic forces and shows all the elements of the motion studied. It is possible to demonstrate by this method of analysis that, of the various motions capable of producing the same final result, some require less expenditure of bodily forces than others. For any mechanical work performed, there is one motion which is the most efficient and which is physiologically the most economical. By adopting these economical motions, jobs can be improved and solutions can be found which in each case represent the best functional conditions. The workers can then accomplish their task with a minimum expenditure of

physiological effort, thereby experiencing less strain and fatigue. In jobs involving repetitive motions, it is possible to determine the most economical speed. It is the one at which the various muscles are functioning at the lowest cost as indicated by the least force required. When a motion involves weight transport, the weight helps the motor forces or the braking forces according to the direction of the motion, and the mechanical work produced is not proportional to the physiological effort resulting from the muscular contractions. A given mechanical work expressed in foot-pounds may correspond to muscular efforts that are quite different according to the way of doing the work, according to the weight involved and according to the speed of motion. Such experiments demonstrate that the external work produced is only one factor in the study of fatigue and that "fatigue allowances" based exclusively on external work are misleading. By definition they do not take into account the braking forces acting in every motion. These forces which represent a mechanical loss in the total performance participate, nevertheless, in the physiological cost of any muscular activity and are, therefore, a contributing factor to fatigue and to the duration of the recovery period.

When the various motions performed in a job are studied, a complex curve is obtained which is always the same under identical conditions of performance. The amplitude of the recorded forces is proportional to the corresponding efforts, whether they are producing or braking the motions.

The geometrical conditions under which motions are performed to achieve a specific result have a definite influence on the forces involved. As an example, Figure 10 shows the efforts produced in the three dimensions while loading textile bobbins at various heights on a special buggy mounted with five rows of pegs. As recorded, loading the second row does not require much effort and comparable results are obtained while loading the first, the third and the fourth row. On the other hand, loading the fifth row at the bottom of the buggy involves bending the knees and straightening up. It is clear that the forces involved in that motion are considerably greater and, consequently, loading the fifth row is not economical. It requires more energy expenditure than loading the other four rows and is an unwarranted addition to the physiological stress and fatigue in the over-all operation.

Another example, given in Figure 11, compares the efforts needed for opening and closing the five drawers of a standard filing cabinet. The efforts necessary to accomplish these operations vary according to the height at which the drawers are located. The total efforts calculated from the three components are the same for the top and for the second drawers and amount to 16 kilograms. They increase to 21 kilograms for the third, 30 kilograms for the fourth and 42 kilograms for the bottom drawer. Consequently, using the

bottom drawer is definitely the least economical. It necessitates stooping and rising which require the action of important forces and a comparatively large expenditure of energy.

In order to show how delicate the method can be, Figure 12 compares two records of the forces developed by the same typist, typing the same text on a manual typewriter and on an electric typewriter. The total efforts calculated from the three components are reduced by approximately 50 per cent when the electric machine is used.

The preceding examples lead to the conclusion that physiological techniques should be introduced in work measurement. It should be realized that from a practical point of view, the problem is not simple. It will be solved only if a well-coordinated and systematic program is developed to determine, first, the physiological cost of basic industrial operations. Later on, more specialized jobs and environmental conditions will have to be studied so that, progressively, the physiological cost of most occupations will be known. A new branch of the scientific study of man must be built up; namely, "industrial physiology" or, in an even broader scope, "occupational physiology." When that is done we will be able to evaluate precisely the human element in any given job and to establish, on sound basis, the time sequence of work cycles and rest periods that achieve maximum efficiency at minimum physiological cost. The results will prove, disprove or correct the basic values of predetermined motion-time data frequently used in work measurement. In due course it will be possible to replace the notion of "mechanical work cycle" by the concept of "physiological work cycle." The latter includes not only effort per unit of time multiplied by duration of operation but also the physiological recovery time. This will give a more accurate picture of the effort required by the worker and will furnish quantitative data for estimating fatigue which remains an essential factor in the utilization of human labor. When more information is available, it will be possible to formulate laws of physiological economy of performance which may not necessarily coincide with motion economy as it is now understood.

As long as work organization and production standards are established without considering the physiological reactions of the workers, no real solution to the problem of human labor will be found. It should be pointed out that frequently grievances and strikes originate in poorly established work standards. The judgments of the industrial engineers and that of the workers are not always in accord as to what should be considered a "fair day's work." In the absence of factual data permitting precise evaluation of what a worker can do within safe physiological limits, time consuming discussions arise. They usually end in a compromise

which quite often is unsatisfactory to both management and labor.

On the other hand, when information on the physiological reactions of the workers to a given job is available, there is a sound basis for discussion, and scientific facts can be used to reach a reasonable solution. Such situations have occurred and the use of physiological data has lead to job reorganization that has been well accepted by the employers and the employees. The adoption of physiological techniques will help work measurement become a science rather than an art.

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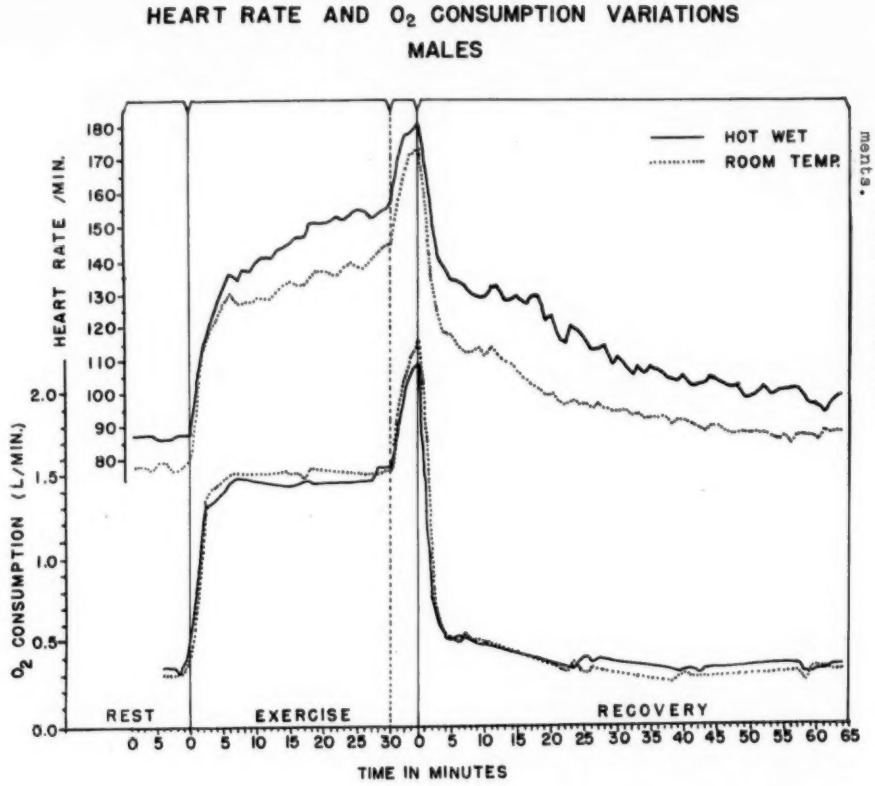


Figure 1 - Heart rate and oxygen consumption variations during exercise at two work loads and during recovery. These experiments are performed in two different environments.

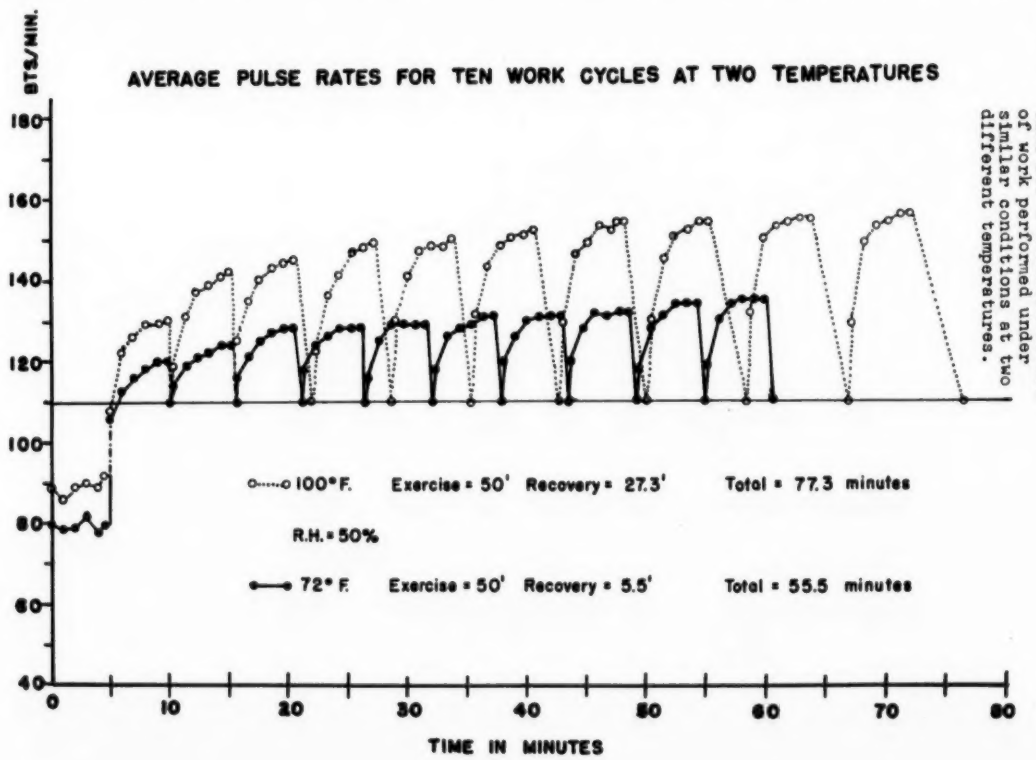
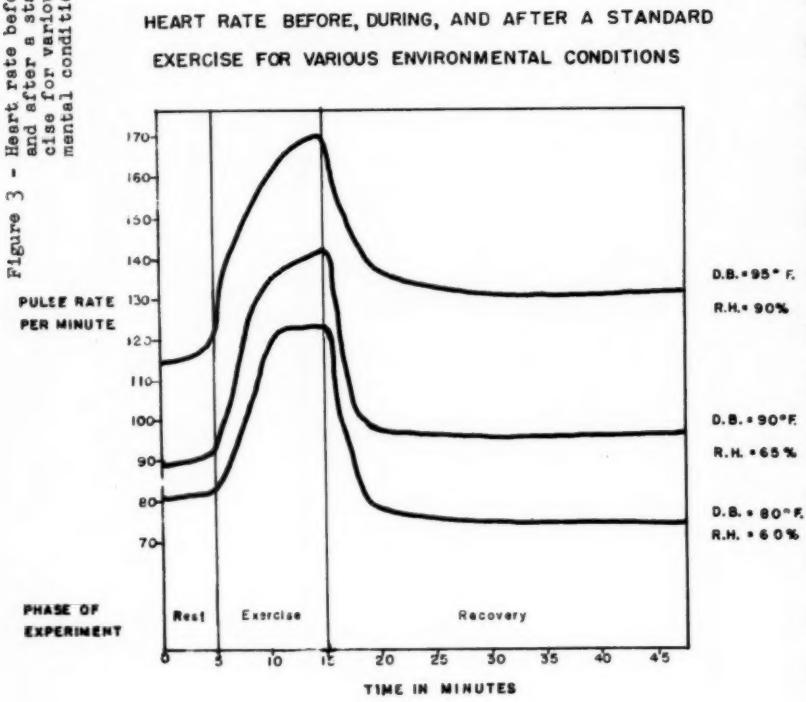


Figure 2 - Heart rate and recovery time for a standard amount of work performed under similar conditions at two different temperatures.

Figure 3 - Heart rate before, during, and after a standard exercise for various environmental conditions.



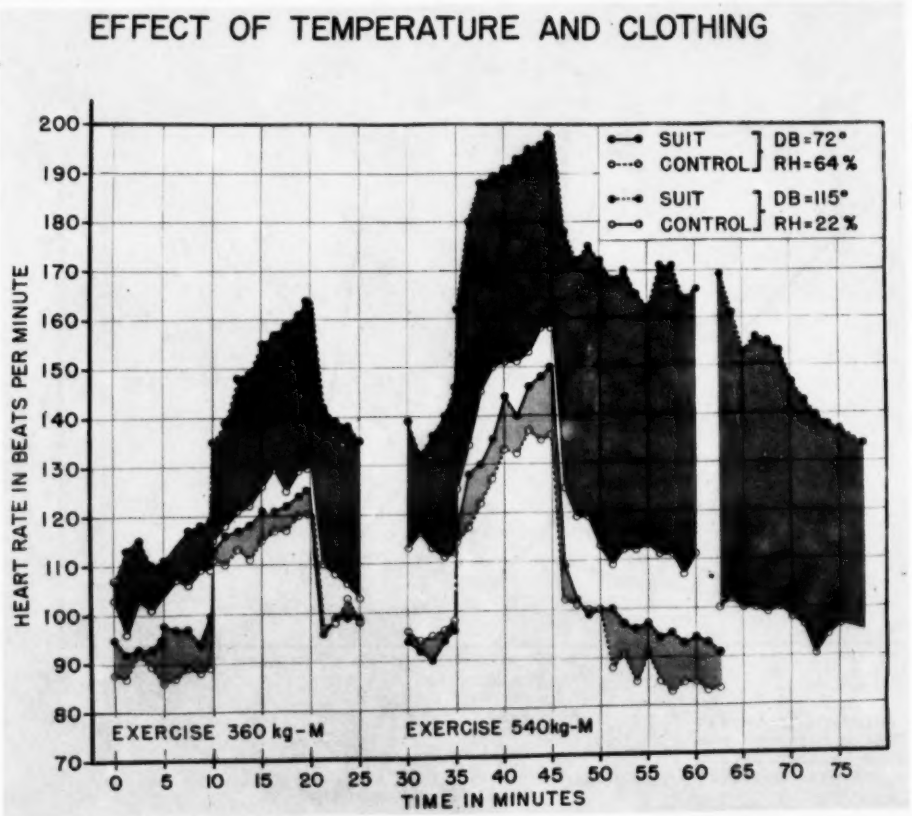
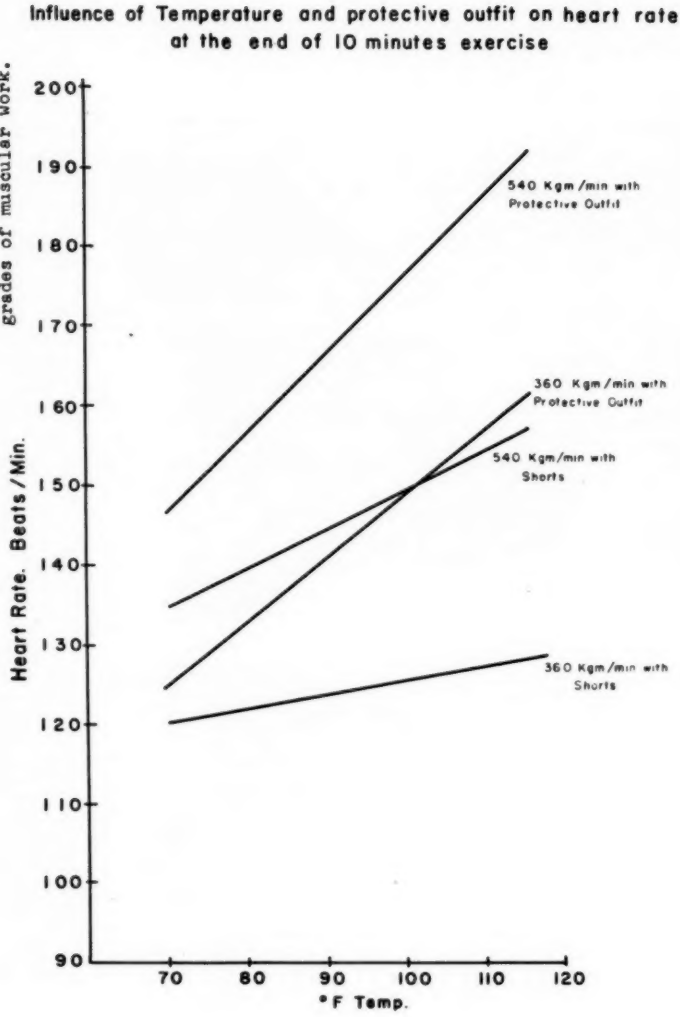


Figure 4 - Effect of temperature and clothing on heart rate at rest, during two grades of muscular activity and during the recovery periods.

Figure 5 - Relation between heart rate, environmental temperature and clothing during two grades of muscular work.



Influence of Dry Bulb Temp. on Heart Rate Recovery Curves

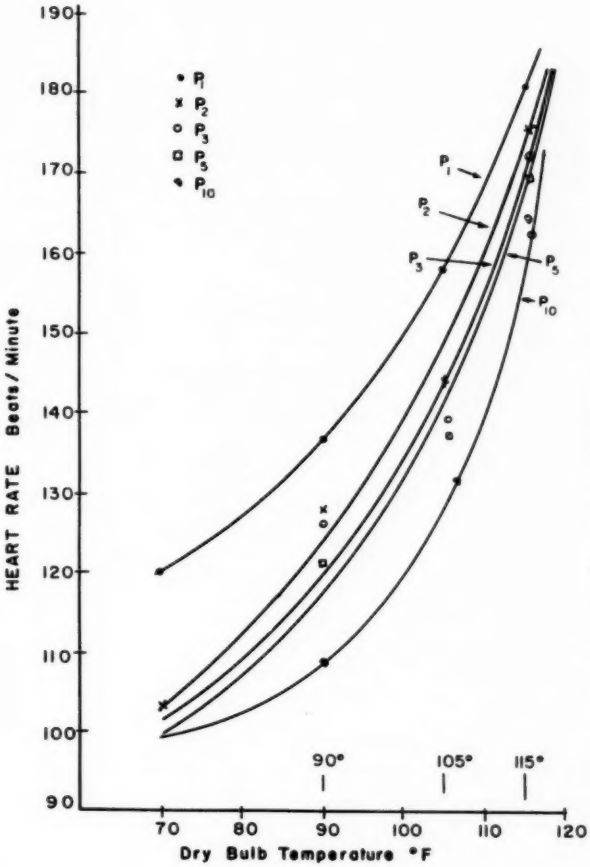
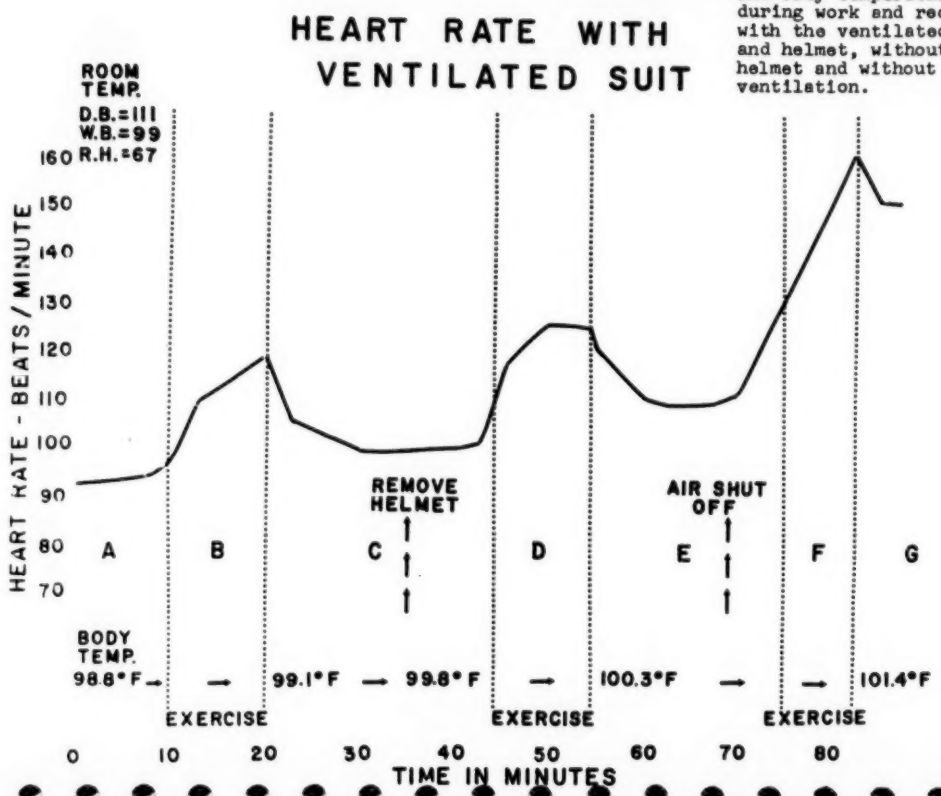


Figure 6 - Relation between heart rate and environmental temperature during the recovery period after work.

Figure 7 - Variations in heart rate and body temperature during work and recovery with the ventilated suit and helmet, without the helmet and without the ventilation.



EFFECT OF VENTILATED SUIT

ON HEART RATE RECOVERY CURVES

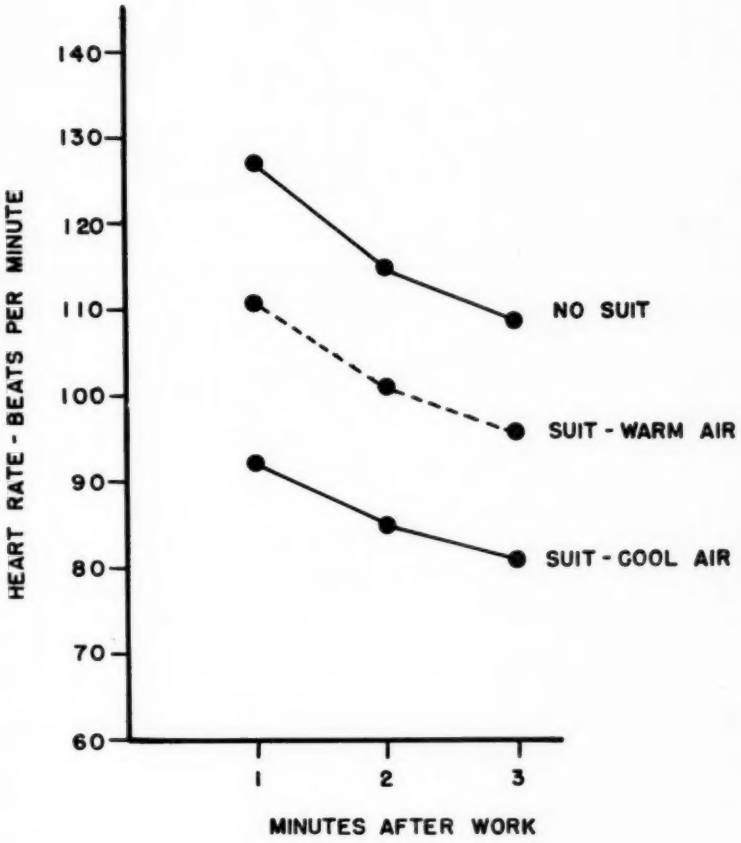


Figure 9 -/

Forces involved in bending the knees and straightening up as recorded by the Lauru Platform in the vertical, frontal and transverse components.

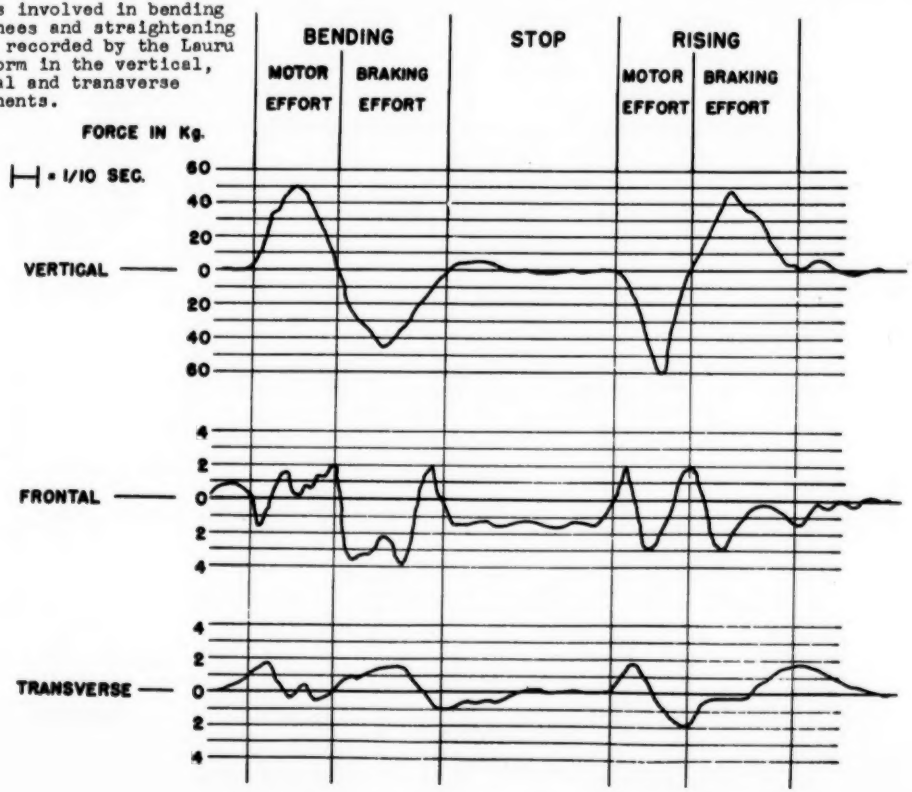
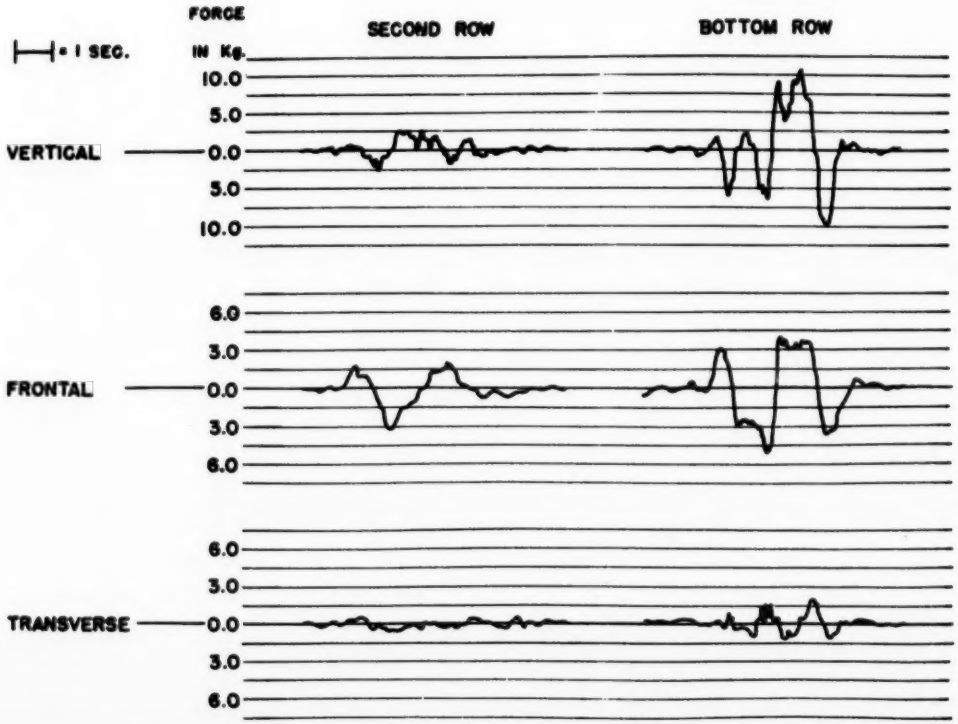


Figure 10 - Forces involved in handling textile bobbins at various heights.



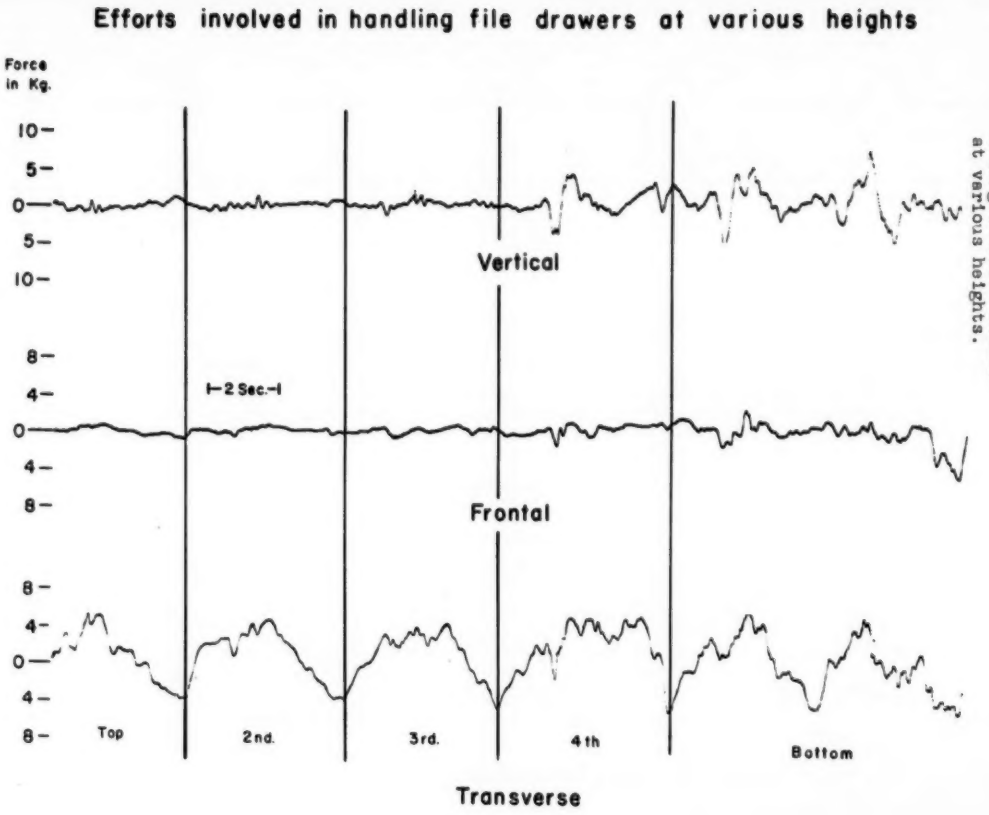


Figure 11 - Forces involved in opening and closing filing cabinet drawers at various heights.

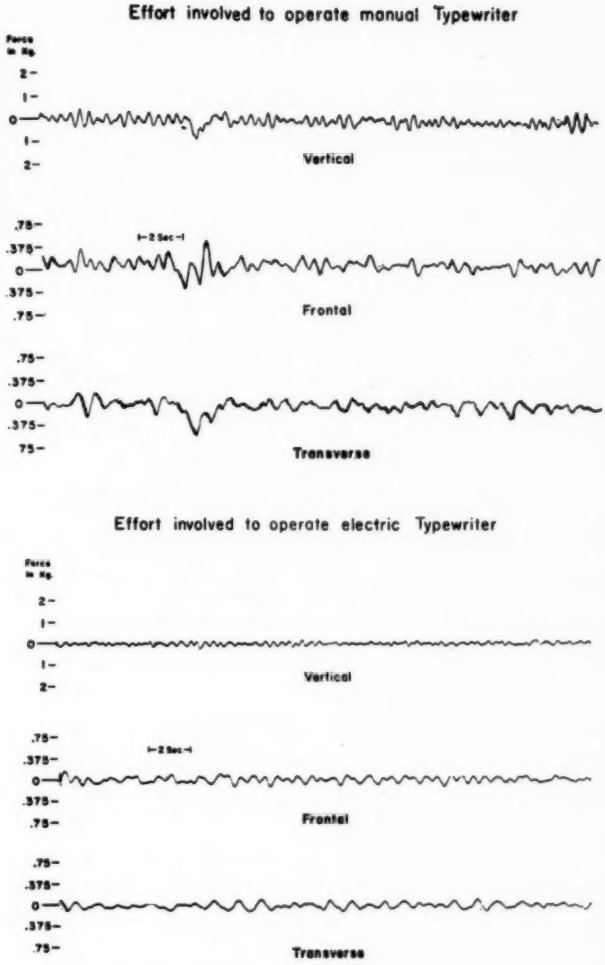
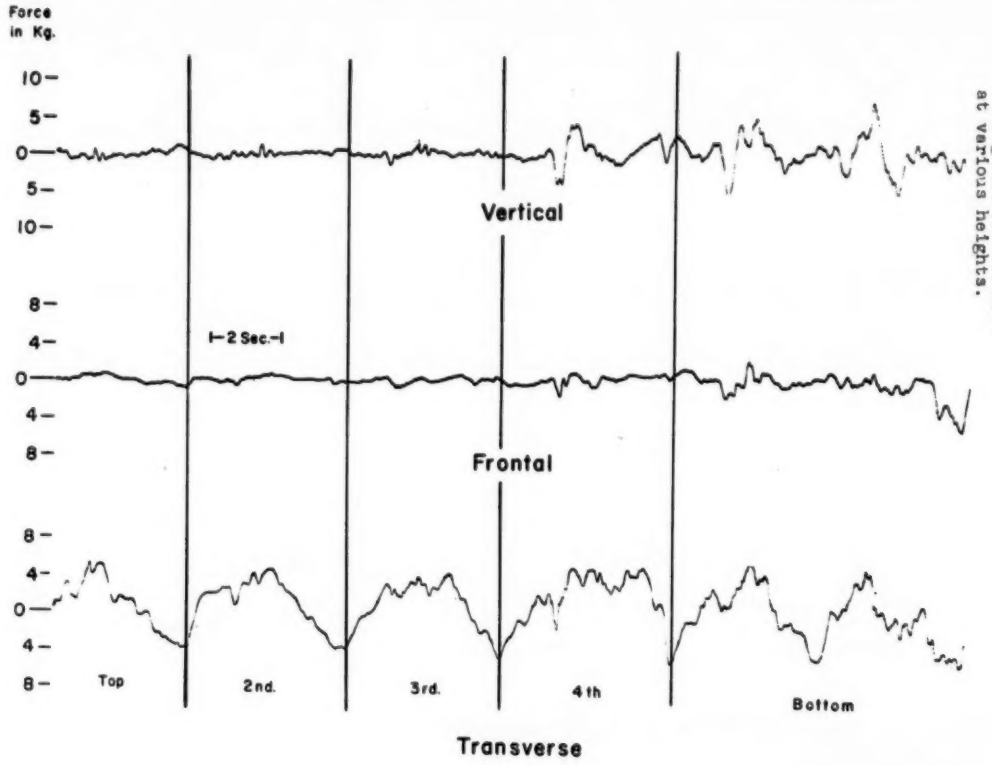


Figure 12 - Forces involved in operating a manual and an electric typewriter. Same typist and same text.

Efforts involved in handling file drawers at various heights



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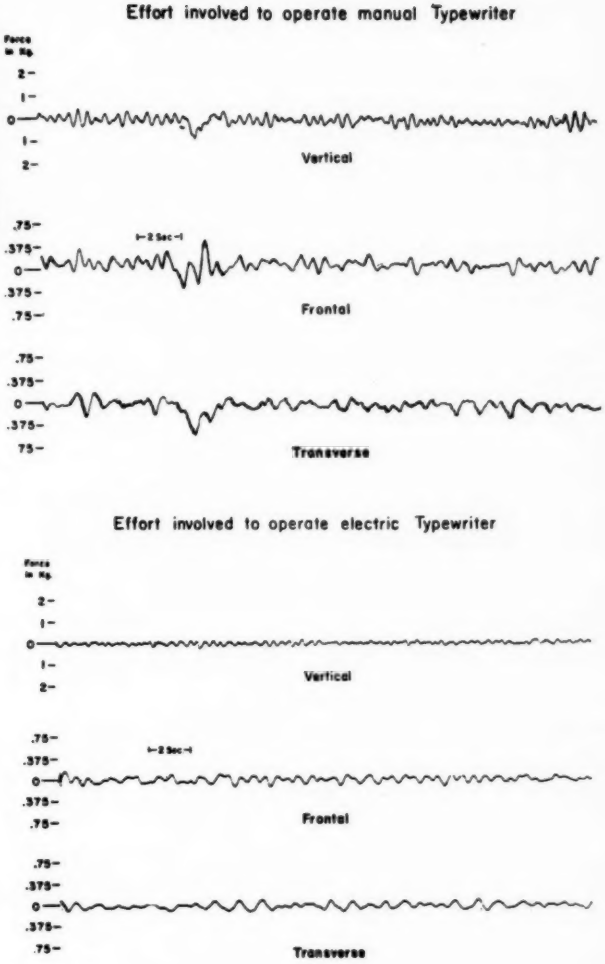

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A CASE STUDY OF INDUSTRIAL ENGINEERING IN OPERATION

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May 16, 1957

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A CASE STUDY OF INDUSTRIAL ENGINEERING IN OPERATION

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Herbert Ashcroft
Bausch & Lomb Optical Co.

In any discussion of the Industrial Engineering function in operation, or the application of the tools of the Industrial Engineer, it is appropriate to first discuss the areas in which these functions occur, the organizational setup to carry out the specific tasks and the corporate structure as a basis for appraising the climate under which these functions operate.

The Bausch and Lomb Optical Company was organized 104 years ago to manufacture hard rubber eyeglass frames. Twenty years later the Company manufactured the first microscope made in the Western Hemisphere. Today this Company's sales are in excess of $50,000,000 per year and employs over 6,500 persons.

Approximately one-half of the sales are in the Ophthalmic field and covers such items as industrial safety eyewear, sunglasses, single vision and multifocal lenses, refracting equipment and spectacle frames manufactured in gold filled material, combination of plastic and gold filled and all plastic. The balance of sales is in the Scientific Instrument field and covers a wide range of products such as aerial mapping equipment, microscopes, optical measuring instruments, (colorimeters, refractometers, contour projectors) projection apparatus and photographic camera lenses such as the famous Cinemascope.

The manufacturing operations are almost fully integrated. The Company manufactures its own glass for optical and ophthalmic use, its Foundry produces ferrous and non-ferrous castings and its Plastics Division makes acetate material for use in plastic frames.

Bausch and Lomb has a functional type organization: Operations, Research and Development, Industrial Relations and Service, Sales and Finance with a Vice President for each division.

The Operations Organization is made up of four divisions:

The Manufacturing Division, under the Works Manager, consists of two Ophthalmic Lens Divisions, Frame Manufacturing, Scientific Instrument, Glass Plant, Engineering and Maintenance (building, machines and tools) and Process Development.

The Production Control Division, under the Production Control Manager, consists of one section in each production division working alongside the Manufacturing Superintendents, Shipping, Raw Materials Stores and in-process and finished inventory responsibility.

Final (or customer) Inspection Division, under the Chief Inspector, consists of one section each in the Lens, Frame and Instrument Divisions working alongside the Manufacturing Superintendents.

The Purchasing Division, under the Purchasing Agent, purchases and expedites material procurement according to requirements.

Industrial Engineering

Prior to 1949, we had, within each Manufacturing Division, Instrument, Lens, Frame, Glass Plant, a Process Engineering and Specifications Department responsible for estimating and converting blueprints to layout sheets plus a centralized Time Study and Methods Engineering Department working from one office with representatives in each division.

In 1949 the Process Engineering and Methods Engineering Departments combined under the name Factory Engineering Department with one such department reporting to each Manufacturing Division Superintendent. A centralized Industrial Engineer was on the Works Manager's staff for functional control.

Late in 1949, the Works Manager with the Superintendents issued a "charter" listing the duties and responsibilities of the newly organized Factory Engineering Departments. This has remained substantially as originally written. The following is an abbreviated list of the basic duties:

1. Interpret blueprints and specifications on products.
2. Co-operate with Product Engineers to promote design economy.
3. Develop and write process layouts.
4. Estimate product costs, regular line and customer orders.
5. Establish normal costs for product cost control and reporting.
6. Establish and maintain excess and scrap controls.
7. Determine and order required product tools necessary for manufacturing.
8. Develop and maintain quality records as required.
9. Where required, establish and maintain material codes.
10. Determine source of materials or parts - whether purchased or manufactured.
11. Recommend the acquisition of equipment for specific new applications.
12. Create and apply standard data - make time studies.
13. Maintain divisional equitable wage standards through staff Industrial Engineers.
14. Responsible, under divisional Superintendent, for product costs.
15. Initiate and execute cost reduction programs within respective division.
16. Initiate other and major cost reduction programs for Superintendent to refer to centralized Process Development Department. Be responsible to Superintendent for acceptance of, applications of, and installation of resulting new process.

17. Handle suggestions.
18. Serve as consultants to other divisions of Company.
19. Recommend departmental layouts for efficient manufacturing.
20. Conduct departments along accepted engineering principles.

Source and Training of Personnel

It is conceived that the personnel for the key jobs in this department are to be of the highest type procurable consistent with our level of operation. From the very definition of the department's function, it is obvious that such a department should be the cradle for future key personnel for any division of the Company. Manpower flowing into the department should be of two types; one from technical schools and universities in the form of young engineering talent to be trained in industry and the other from the shop in the form of key personnel who show promise of development into future line supervision.

It is felt that the department activities and responsibilities fall into two broad channels. These are Planning and Control. Basically, planning is the delineation of responsibilities and objectives or missions. Control is establishing department organization and intra-departmental relationships.

Through this Factory Engineering setup, future supervision, both operating and technical, is most easily developed by job rotation among the factory departments, quality control departments and the factory engineering departments.

Our experience at Bausch and Lomb has been outstanding in this direction. Since establishing this policy, we have trained and filled the following positions by promotion from this Department:

2 major divisional superintendents
2 assistant superintendents
4 factory engineering department heads
3 factory inspection department foremen
3 manufacturing engineers
5 manufacturing department foremen
7 manufacturing department assistant foremen
4 product engineers transferred to Research and Engineering Division

A total of 30 promotions.

Future of Industrial or Factory Engineers in Industry

As mentioned previously, industry is becoming more and more technical with each passing month. More candidates with scientifically trained background are required to plan and control the complicated operations. Whether we like it or not, we are trending towards "bigness" in every phase of our economic life. Farms are growing larger, chain stores are replacing independents, diversification and mergers are the

every day concern of manufacturing institutions. Public utilities are branching out to nuclear power sources, even service organizations within industry are mechanizing and developing economies through data processing equipment. All this requires more engineering talent.

Our educational system is not producing this additional talent, they are falling far short each year and the accumulated shortage is alarming. It behooves industry therefore, to plan compensations for these conflicting conditions. It becomes necessary to organize to obtain maximum utilization of available engineering talent. Do not overlook the source of technicians in your factory departments. Utilize them under experienced engineers for the less technical positions and jobs. Study what each experienced engineer does throughout the day to insure they are not performing functions that can just as easily be handled "down-the-line". Establish the missions or objectives of your staff engineering departments to minimize overlapping with your line departments. Establish and define the various levels of Industrial Engineering. Inventory your talent in each bracket and compare with your position requirements. This scientific approach at least will show you where you are and where you should be. With such a talent "road map" your every move can be a step in the right direction.

Application of the tools used by the Industrial Engineer is a full time effort at our Company. Because of the diverse products we manufacture, we have a wide range of processes covering all the basic engineering skills, such as chemical, optical, physical, metallurgical, mechanical and ceramic. We also have a wide range of problems requiring solution. The Industrial Engineer is called upon to work in the areas of:

1. Incentive applications and the measurement of work.
2. Process capabilities
3. Machine utilization
4. Methods improvement
5. Quality improvement - elimination of waste
6. Product cost analysis and reduction
7. Process mechanization
8. Material improvement and control

The economics of many Industrial Engineering assignments can not ascertained easily. Tangible benefits can be measured when product costs are reduced through process changes, methods improvement, changes in materials or feeds and speeds of equipment. Gains can be tabulated in greater machine utilization or improved process yields. Much of the work of the Industrial Engineer is in the area where benefits are difficult to measure; such as basic research, developing procedures for better work measurement, process limitations, cost estimating, service to flanking organizations in an effort to avoid production bottlenecks, new product debugging, surveys for plant capacity, training and development of other Industrial Engineering personnel.

Let us examine some of the examples of Industrial Engi-

neering activity at Bausch and Lomb:

A. Improvement of plant-wide mail and messenger service. Area: 15 buildings, 5 to 6 stories each, 1,216,818 sq.ft.

1. Assignment - Improve mail and messenger service and establish the improved service to a more efficient level.

2. Points of Study -

a. Existing efficiency of pick up and delivery. Several mail boxes chosen at random were used to post date and time mail addressed to the Stenographic Department where it was dated on arrival. Time lapse between posting and delivery was recorded in each case. The data indicated a range from 50 minutes to two days with a mean value of three hours. The advertised schedule was one hour.

b. Influence of absenteeism on efficiency. Lacking historical data for sampling, absenteeism was recorded as the study was undertaken. Within a short period of time, it was found that the group absenteeism was considerably greater than the Company-wide average. There were six routes to be covered for which eight persons were employed. Two of the eight persons were held as reserve. 320 hours were being used to accomplish an assignment requiring 240 hours per week. Under normal absenteeism, breakdowns in the service would occur only if three persons were absent simultaneously.

c. Number of routes and routes traveled. The six routes that were laid out for service required 25 - 30 minutes to cover. In the study it was found that individual rather than departmental service was being rendered in many areas. Also, there was no policy governing delivery or locations of delivery and pick up points. As no documentation of trip routes was available, it was not known whether the actual routes taken at the time of observation were the originally planned routes or the result of degeneration over a period of time.

Recommendations made and carried out:

1. Trip layouts prepared to accomplish maximum efficiency with least travel on part of personnel. Routes reduced from six to four. Average trip not to exceed 25 minutes.

2. Permanent assignment of routes discontinued and a system of rotation was adopted making each person equally efficient on all routes.

3. Color of mail pick up and delivery boxes was standardized for ease of location and boxes placed so as to minimize entry into departments.

4. All plant-wide trips scheduled for one hour 30 minutes with all trips departing at the same time. This would guarantee that mail picked up on one trip would be delivered on next trip. Trips to be signed in and out of mailroom and random ratio delay studies be made to ascertain adherence to new procedure.

Savings

1. Reduction in operating cost of 50%.
2. Increased efficiency.
3. Greater versatility among the group.
4. A gain of 12 hours of time per day for other work.

B. Optical filming (metallic and non-metallic)

By way of background, it should be noted that this entire field is only slightly over 20 years old, as an industrial operation. Metal films for reflectors date from about 1934, and anti-reflection films from about 1939. World War II caused feverish development and expansion activity. Much basic development is still going on. The operation involves the precise application of physical principles of high vacuum, with corresponding difficulties in equipment from an operational and maintenance standpoint. These difficulties, coupled with a diversity of product and a continued adding of new technical developments, had given rise at Bausch and Lomb to a bottleneck in delivery of the optical elements necessary to several areas of the business.

1. Problem

To determine the reason or reasons for the inability of the magnesium fluoride Evaporation Department to meet production requirements on a sustained basis, and to recommend specific corrective action.

2. Points of Study -

a. Fifteen filming units were involved, employing five operators on each of two shifts.

1. Desired to determine what percentage of equipment time was spent on each of the seven phases of the filming cycle (i.e. Load, Fore-pressure, Hi-Vacuum, Fire, Cool, Unload and Empty).

2. Desired to determine what percentage of personnel time was required for operation of the equipment. Operators were tabbed as

"Working" or "Idle".

b. A ratio-delay or work sampling type of study was planned and carried out. A stratified random sampling plan was used; 300 observations per day were made of the equipment, and 100 per day of the personnel. Period of study was one week, which, checking with production records, indicated to be typical with respect to kinds and mix of work.

c. Analysis of the data revealed -

1. Four of the fifteen machines accounted for 52% of the "Empty" time.

2. Two operators accounted for 61% of the observations recorded as "Idle".

3. The time for "Cooling" was found to be running at nearly 50% of the "Hi-Vac" instead of the 25% on which the process was originally based.

d. Conclusions resulting from the analysis were -

1. The discrepancies noted were caused by lack of cleaned work available for filming and by an "in process" inventory which was inadequate to utilize full machine and operator availability.

2. A considerable proportion of the "Empty" observations for <u>all</u> machines occurred during the first two hours of the day. This was directly attributable to a lack of proper cooperation between shifts, with the night-shift failing to leave an adequate supply of cleaned work ready for filming by the day shift.

e. The recommendations resulting from the conclusions were -

1. That the cleaning staff be augmented to provide adequate cleaned stock.

2. That a system be set up to provide an adequate work supply for change of shifts. Specifically, each shift should leave fifteen cleaned runs for the next shift.

3. That Production Control provide that first work laid out for cleaning, at the start of each shift, be for runs having a minimum number of lenses (i.e. lenses of larger size).

4. That the "in process" inventory be increased by an approximate 50%.

3. Results obtained after recommendations were acted upon -

   a. Work output increased by 50% without increase in number of operators (N.B. one filming operator was re-assigned to cleaning). In terms of increased work output, the saving amounted to $40.00 per day or $200.00 per week.

   b. Production schedules could be met on a sustained basis without additional equipment.

   c. Stabilized operation permitted sound methods studies which will result in near future in improvements in the basic cycle with an even greater gain in labor and equipment productivity.

C. Production of super-precision, machined parts (i.e. mating focusing threads of better than "Class 3" fit)

1. Problem

   Class 2 threaded parts had previously been supplied by an outside vendor who produced them on multiple-spindle automatic machines. After B&L had filled one order to the customer's original design specifications the customer came forth with a new performance specification which required better than "Class 3" fit. The original vendor who had supplied these two mechanical parts to Bausch and Lomb was not able to meet the tighter specification. Thus, the assignment was to find means of providing these parts to the new requirement without increasing the cost of the product.

2. Points of study

   a. Could multiple-spindle equipment be installed with full assurance that the required precision and accuracy of parts manufacture could be achieved?

      Answer: The prospective equipment supplier could not give this assurance.

   b. Would it be feasible to fit mating parts at the time of fabrication?

      Answer: The idea was theoretically sound but impractical in actual operation; each part required separate assembly, on different cycles, to different subassemblies of the

instrument.

c. Could equipment already available at Bausch and Lomb be used to produce the parts with proper tooling and in-process controls?

Answer: Statistical process capability studies demonstrated quantitatively that these parts could, in fact, be provided to the requisite class of fit, using existing equipment, using proper tooling. However, it was shown to be essential that proper precision measuring equipment be provided to allow variables measurements to be made. Furthermore, application of statistical quality control charts was found to be necessary to provide information so that machine adjustments could be made at the proper time and in the proper amount. The above points were embodied in a detailed recommendation.

3. Results obtained after recommendations were acted upon -

a. Parts were produced at Bausch and Lomb with sufficient precision and accuracy to allow random assembly.

b. Available machine equipment was found to be adequate for the job.

c. No increase in product cost was necessary.

d. The production control function was simplified.

e. Better understanding of the capabilities of Bausch and Lomb equipment was achieved; this "know-how" has now been extended to other products.

The foregoing examples are typical case-histories of Industrial Engineering activity at Bausch and Lomb. Similar activity is continually occurring in all the fields mentioned earlier. A valuable by-product is also realized in these studies by the assignment of junior engineering personnel to the various projects, to the fullest extent possible, thus allowing them to gain tangible experience in the use of the more sophisticated techniques. In this way, Industrial Engineering is simultaneously accomplishing its daily tasks and providing for the professional development of personnel against future needs.

APPLYING STATISTICS TO INDUSTRIAL ENGINEERING
(Abstract)

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A number of articles in current literature have been concerned with the use of statistical analysis of Industrial Engineering Data. The Bibliography at the end of this paper presents a selected list of some of these articles. It is the purpose of this paper to present some of the fundamental concepts of statistics which are applicable to Industrial Engineering.

Since our audience is composed largely of Industrial Engineers it will not be necessary to attempt to define what is meant by Industrial Engineering. However, as the work "statistics" means different things to different people, it might be well to define the scope of statistics as it will be used in this paper. The scope of statistics includes the design of experiments in industrial studies, the summarization, analysis and presentation of numerical data.

Thus this paper will be concerned with determining how statistical methods can provide objective means for answering questions that arise in collecting, analyzing and presenting numerical data. For example, statistical methods can provide aid in answering the following questions:

How much data should be collected to get reasonably accurate estimates?

What statistical measures should be determined from the data? How reliable are these statistical measures?

Are the data consistent? That is, will analysis of the data provide a reliable means for describing and predicting results from a particular operation?

Is there a relationship between a particular operating variable and the measured result of the operation?

How much of the variation in results is explainable by the operating variables which have been taken into account and recorded?

Is the operation sufficiently standardized so that sample measurements can be taken as representative of "essentially uniform" operation conditions?

A fundamental concept underlying industrial statistics is the concept of a universe or population from which samples of data are obtained. Thus an eight hour time study is a sample of all of the time studies that could be made of a particular operation. A work sampling study over a two week period is a sample from the population of all of the possible results that could be obtained over the long run. We would like to know exactly what the population being sampled is composed of so that predictions of the future can be made with confidence. However due to limitations of time, money etc. we must be satisfied with the results of samples. Analysis of the sample data provides only an "estimate" of the population.

The estimates made from samples will not agree exactly with the population parameters or true values. Statistical methods provide objective means of evaluating the sample data to give the best estimates of the population parameters in addition to giving a measure of the reliability of these estimates. The statistical concepts underlying basic sampling theory, Shewhart control charts, regression and correlation analysis, confidence limits and tests of significance will be discussed.

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THE VANGUARD SATELLITE LAUNCHING VEHICLE

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Martin - Baltimore

During the International Geophysical Year - from July 1, 1957, until the end of 1958 - - the United States will participate in a world-wide endeavor to obtain information regarding man's environment. Many of the scheduled projects are designed to obtain more exact or more complete information in areas which have been previously explored (Ref. 1). However, there is one undertaking which in many respects is entirely new. That is the scientific satellite program.

Shortly after the Presidential announcement of July 29, 1955, declaring the intention of the United States to place an instrumented satellite in orbit, The Martin Company, Baltimore, was selected by the Naval Research Laboratory as the prime contractor for the launching vehicle.

The initiation of this project was a first step into an era of knowledge, the extent of which cannot even be predicted at this time. In many ways it is not unlike the voyage of Columbus to the New World, since the information sought high above the earth is either distorted or completely hidden from our present observation. Consequently, Project Vanguard presents us with a challenge to accomplish something never before attempted, and an opportunity to extend man's knowledge of the universe.

Fig. 1 is an artist's conception of the Vanguard three-stage vehicle. The structure surrounding the rocket is a gantry crane used to erect and assemble the vehicle and to provide work platforms from which the field crew can test the rocket prior to launch. Behind the gantry is the concrete blockhouse from which the rocket operation is monitored prior to and during flight.

All final tests are remotely performed by the personnel located in the blockhouse, and when the rocket is ready for flight it is fired from this remote location. As seen in Fig. 2, the Vanguard launch stand is somewhat different from that used with Viking. Instead of the large concrete pit employed to conduct the exhaust gases away from the rocket, we use an elevated stand and a steel exhaust duct.

The Vanguard vehicle is without fins. So far as we know there never has been a large rocket flown without these stabilizing components. However, we are confident that the vehicle can be adequately stabilized through the use of a gimbaled engine. Consequently, the fins were removed to reduce structural weight.

The rocket (see Fig. 3) is composed of three stages which partially fit inside one another. The first stage, built by Martin and powered by a liquid rocket engine designed and manufactured by the General Electric Company, burns liquid oxygen and kerosene.

As seen in Fig. 3, the thrust cylinder itself extends aft of the rocket structure. This thrust cylinder is moved by hydraulic actuators in a gimbal system so that flight path control may be effected.

Forward of the engine installation is the tank of hydrogen peroxide, which is used after decomposition to high temperature steam to drive the turbine that powers the propellant feed pumps. In the next compartment

are the spheres containing helium, used to pressurize the fuel and liquid oxygen tanks. Forward of the helium spheres are the fuel tank, the liquid oxygen tank, and the shirt which connects the first and second stages.

The propellant tank walls also serve as the structural skin of the rocket. This structural design approach, which also was employed for the Viking rocket, saves considerable weight. The first stage is approximately 44 feet long with a maximum diameter of 45 inches.

The second stage of the Vanguard vehicle contains a liquid rocket engine, which burns white fuming nitric acid and unsymmetrical dimethyl hydrazine. This engine, together with its associated tankage, is being designed and manufactured by the Aerojet-General Corporation, Azusa, California. A gimbal mounting system and hydraulic actuation units similar to those employed in the first stage are used for control of the thrust vector during second stage burning.

The propellants for this stage are forced into the combustion chamber by high pressure in the tankage rather than through the use of pumps. The oxidizer tank is located aft with the fuel tank forward. The sphere which is between these two tanks contains the high pressure helium employed for pressurization.

Forward of the fuel tank is the equipment section, which contains the required guidance, attitude reference, control, telemetering, and instrumentation packages. The reference system consists of three integrating rate gyroscopes.

The guidance system contains two basic items, a pitch programmer and an integrating linear accelerometer. The pitch programmer provides the vehicle with the necessary in-flight intelligence to allow it to follow the desired flight trajectory that was chosen and preset prior to launch. Velocity information obtained from the integrating accelerometer allows for in-flight correction to the satellite injection time in the event that the vehicle performance does not match the pre-launch estimates.

The three-axis gyro reference system installed in this section will be supplied by the Minneapolis-Honeywell Regulator Company, Minneapolis. The magnetic amplifier portion of the autopilot has been subcontracted to Vickers Electric Division of Vickers, Incorporated, St. Louis, a unit of Sperry Rand Corporation. The coasting time computer, containing the integrating accelerometer, will be supplied by Air Associates, and Designers for Industry is responsible for the program timer.

There is a protective skin around the third stage rocket motor which is considered to be part of the second stage since it remains with this stage when the third stage is fired. The second stage is approximately 31 feet long and has a maximum diameter of about 32 inches.

The third stage is a solid propellant rocket for which a dual development program now is being conducted by both the Grand Central Rocket Company, Redlands, California, and the Allegany Ballistics Laboratory, Cumberland, Maryland. This stage contains the solid rocket motor and the satellite which is a 20-inch sphere weighing approximately 21 1/2 lbs.

The satellite sphere is enclosed within the nose cone of the vehicle which will be jettisoned during the second stage powered flight.

Adding together the length of the individual stages will not give the correct length of the Vanguard vehicle, because the stages fit partially inside each other. The overall length is approximately 72 feet and gross weight at takeoff is approximately 22,600 lbs. The Viking was about 45 feet long and weighed approximately 15,000 lbs. at takeoff.

In order to achieve the required performance the rocket must have an exceptionally light structure. This implies the use of very light-weight materials, such as aluminum and magnesium, and the employment of advanced structural design and manufacturing techniques. Consequently, the properties of many materials were investigated and several engineering solutions to design problems were studied before a final configuration was released.

A typical solution to one of these problems is the design of the first stage fuel tanks, which employ a single welded-aluminum wall for both tankage and rocket structure.

First, the tank ends and the cylindrical section are made separately. The required strength of the cylinder is obtained by spotwelding to doublers. Fusion welding is used for sealing. The ends and cylinder are then joined by scalloped fusion welds to form a complete tank. This assembly is then tested for leaks with low pressure. If there are no leaks it is then pressure tested, cleaned, and calibrated.

Each Vanguard rocket must successfully pass at least five complete tests before it is fired. These are the horizontal and vertical tests at the factory and the horizontal tests, in the hangar, followed by vertical tests prior to static firing and launch in the field. A typical sequence of tests in the factory is shown in Fig. 4.

The ultimate test of the Vanguard rocket is the ability to follow a desired trajectory so that an orbit is established.

The satellite orbit that has been tentatively chosen is elliptical, with a 300 mile injection altitude, a minimum perigee (nearest point to the earth) of 200 miles and a maximum apogee (farthest point from the earth) of 1400 miles. The perigee of the orbit is the principal factor in establishing its lifetime. It is estimated that for a perigee of 200 miles, the satellite will stay in orbit for approximately two weeks; for a perigee of 300 miles, one year; and for a perigee of 100 miles, one hour, less than the time required for one cycle of the orbit.

The desirability for restricting the apogee of the satellite stems primarily from the considerations that, as altitude increases, radio transmissions from the satellite become increasingly difficult to receive and also the capability of optically tracking the satellite is attenuated.

The satellite launching vehicle is being designed with the capability of injecting the satellite at an inclination angle of 35 degrees to the equator. Since the inclination angle defines the band of latitude within which the orbit will be contained, it is desirable to have a large inclination angle so that a greater portion of the earth will be covered. As the inclination angle is increased, however, the satellite benefits less from the earth's rotational velocity and consequently would require a higher-performing launching vehicle to achieve an orbit.

Let us now examine the trajectory of the Vanguard vehicle from launch to orbit.

Initially, the vehicle follows a vertical heading, but after ten seconds of flight the internal guidance system tilts the rocket so that a curved trajectory is followed. An artist's conception of the first stage flight is shown in Fig. 5.

The first stage will lift the entire rocket to an altitude of about 36 miles, at which time the vehicle will be moving at approximately 5500 feet per second, when the fuel for the first stage will have been exhausted. The first stage then will be separated from the rest of the vehicle and will fall to earth at an impact point approximately 275 miles down range from the firing site. A view of the vehicle at the time of first stage separation is shown in Fig. 6.

At the time of this separation, the second stage engine will be ignited. The thrust of this engine then will propel the vehicle along a curved trajectory to an altitude of approximately 140 miles at time of burnout. The vehicle then will be traveling at approximately 13,400 feet per second.

In the next phase of flight, both the second and third stages will coast along the trajectory to an altitude of approximately 300 miles.

During this time, the attitude of the vehicle will be controlled by an autopilot which employs small jets of residual second stage pressurization gas. A similar on-off jet control system was successfully flown during the Viking program (Ref. 2). The third stage then will be spun about its longitudinal axis. Spinning will be accomplished by mounting the third stage propulsion unit on a turntable and imparting a torque to the table with small solid rocket units. These solid rockets will be supplied by the Atlantic Research Corporation, Alexandria, Virginia.

After separation from the second stage, the third stage will accelerate the scientific satellite package to a final velocity of approximately 25,000 feet per second before exhausting its fuel. The satellite proper then will be separated from the third stage rocket. The third stage rocket also will become a satellite, since its final velocity is that of its scientific payload.

Once the satellite has been established in orbit, the responsibilities of the Martin Company are essentially over. We have been assigned the task of providing a vehicle which will lift the scientific instruments from the earth to an altitude of approximately 300 miles and establish them in orbit.

The experiments to be conducted and the instrumentation to be employed are the responsibilities of others. For example, The National Academy of Sciences, through its US National Committee for the IGY - which initiated the program - is responsible for the scientific aspects, the experiments and instrumentation, and the radio and optical observations and measurements. The Academy has assigned the US Optical Project to the Astrophysical Observatory of the Smithsonian Institute, and the Radio Project to the Naval Research Laboratory, in addition to the design of the satellite. A number of universities and laboratories have been designated to prepare experiments for possible inclusion in the satellite.

Fig. 7 illustrates the ground track which will be made by the satellite as it revolves around the earth. Since the earth rotates beneath the orbit, the satellite will not pass over the same points on successive revol-

utions in approximately 90 minutes, the ground track will be off-set by approximately 22.5 degrees on the earth's surface on each successive revolution. Most of the world's temperate zone will be covered by the satellite's orbit. Consequently, many observatories will have the opportunity of attempting visual track of the object.

It is interesting to examine the reasons for an elliptical orbit. In Fig. 8, we have a graphical representation of the required velocities and angular accuracies to establish an orbit when the altitude of injection is 300 miles. If we were to have no angular errors, the velocity required for a perfect circular orbit is 25,025 feet per second. However, we must realize that there will be errors not only in the angles but also in the terminal velocity. Consequently, we have drawn curves which show us the allowable combinations of errors which will restrict the orbit to a given perigee and apogee.

In the figure, we have a curve for the 200-mile perigee. If we stay to the right of this curve, we will never come closer than 200 miles away from the earth. In addition, we show the requirements for an 800-mile apogee. We must operate to the left of this curve. As you can see from the figure, the velocity required for circular orbit at 300 miles is quite close to the 200-mile curve. Consequently, if we wished to limit the orbit to a 200-mile perigee and 800-mile apogee, we should actually increase our nominal final velocity, so that we may allow both positive and negative velocity tolerances and may take full advantage of the possible relaxation of angular tolerances.

The actual tolerances in the orbit for the IGY satellite are such that the apogee must be no greater than 1400 miles and the perigee no less than 200 miles. Consequently, the attitude errors allowed are of the order of $\pm$ 2 1/2° and the allowable velocity errors corresponding to this angle are approximately $\pm$ 340 miles per hour. However, we must again increase the nominal burn-out velocity to take full advantage of this situation.

We have examined some of the requirements of the International Geophysical Year satellite program, and have stated briefly the significant features of the launching vehicle without considering the question - - Why do we want an artificial satellite at all?

If you require specific justification for this endeavor, there are many predictable results which will be of immediate practical value. For example, expected data on the physical characteristics of the upper atmospheric-pressure, temperature and density (Ref. 3) - - will be required for future high speed, high altitude airplane design. Triangulation measurements employing a satellite will permit more exact determination of the size of the earth and of the relative locations of the land masses (Ref. 4). In addition, more complete information on solar radiation, cosmic ray intensity, dust concentration, and magnetic phenomena undoubtedly will be of great value to the meteorologist and the physicist.

However, all of the above data relate to the attainment of short-range objectives. The true significance of the project is that we have accepted a challenge to create something never before seen by man, something to be used for the advancement of mankind by extending our knowledge of our environment.

Comparison of Vanguard & Viking Rockets

	Vanguard	Viking
Length	72 ft	45 ft
Diameter (maximum)	45 in	45 in
Take-Off Gross Weight	22,600 lb	15,000 lb
Velocity, maximum	25,000 ft/sec	6100 ft/sec
Altitude at burn-out	300 mi	40 mi
Altitude, maximum	1400 mi	158 mi

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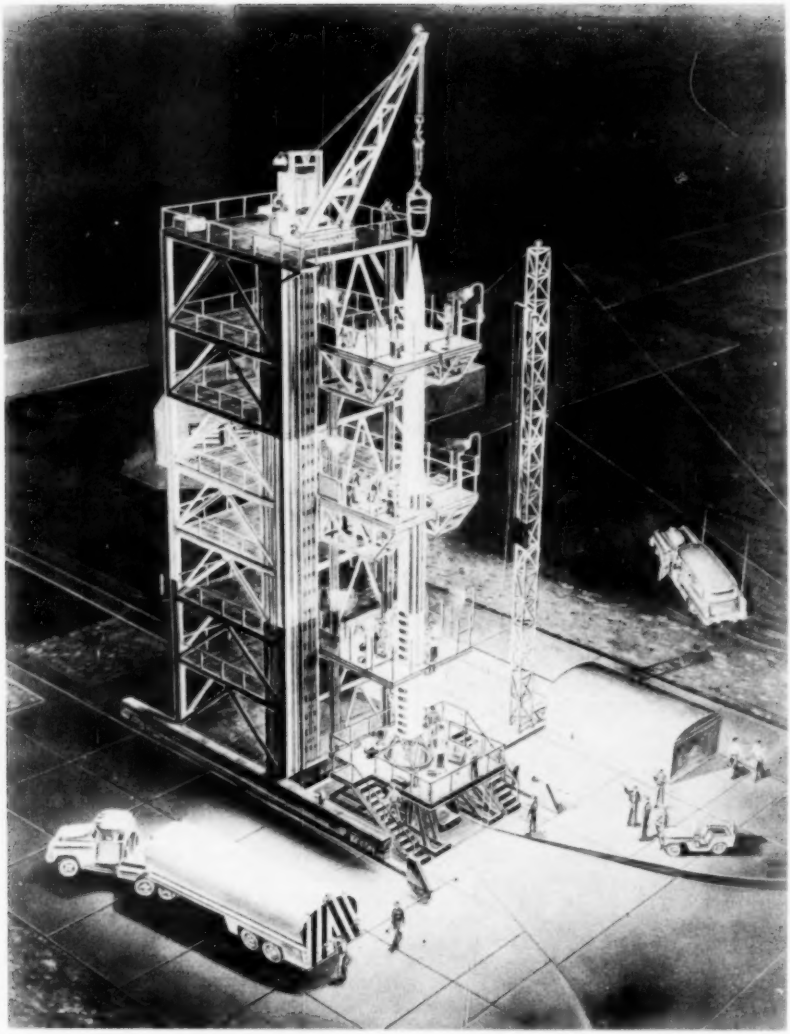

Fig. 1. The Vanguard Vehicle in Gantry Crane

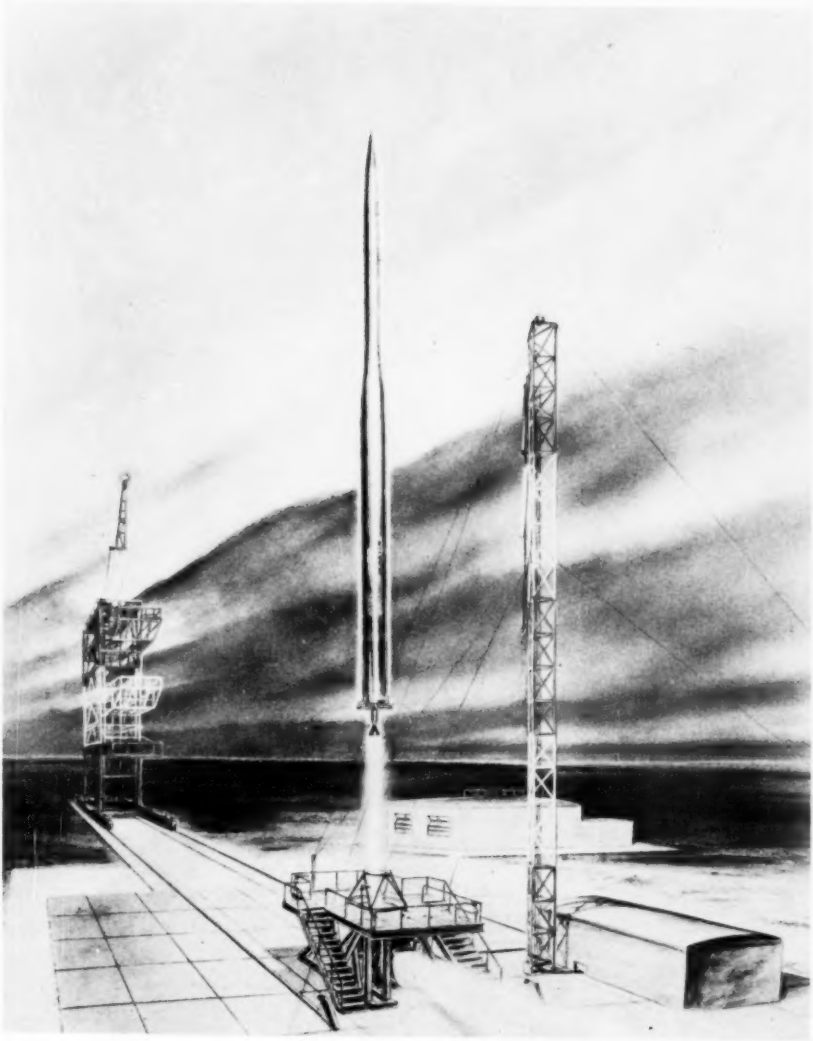

Fig. 2. An Artist's Conception of the Launching of a Vanguard Three-Stage Vehicle

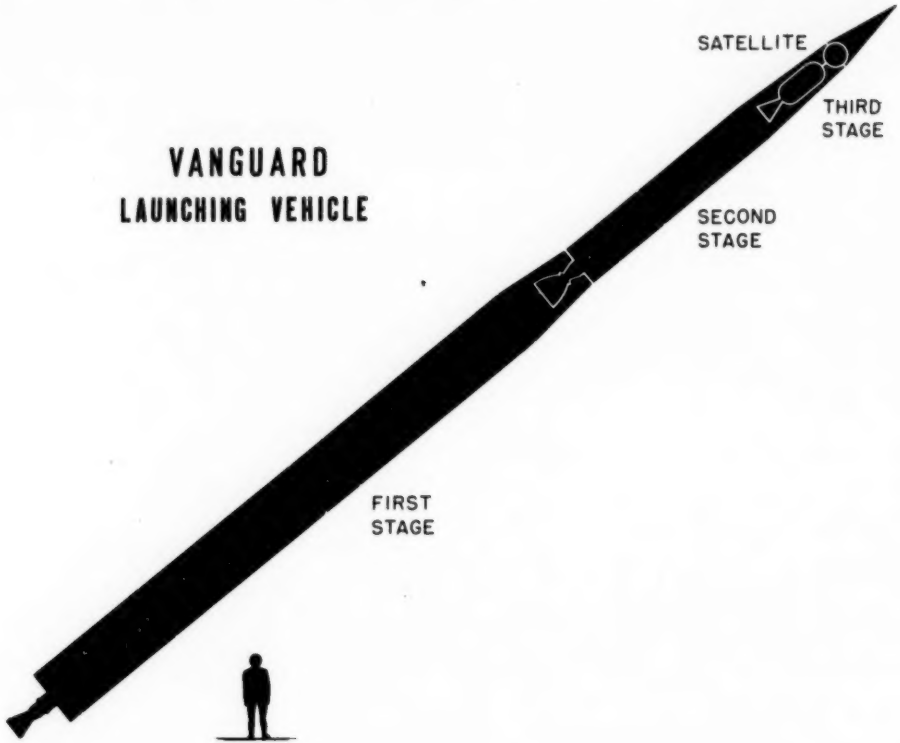

Fig. 3. General Internal Configuration of the Vanguard Rocket Vehicle

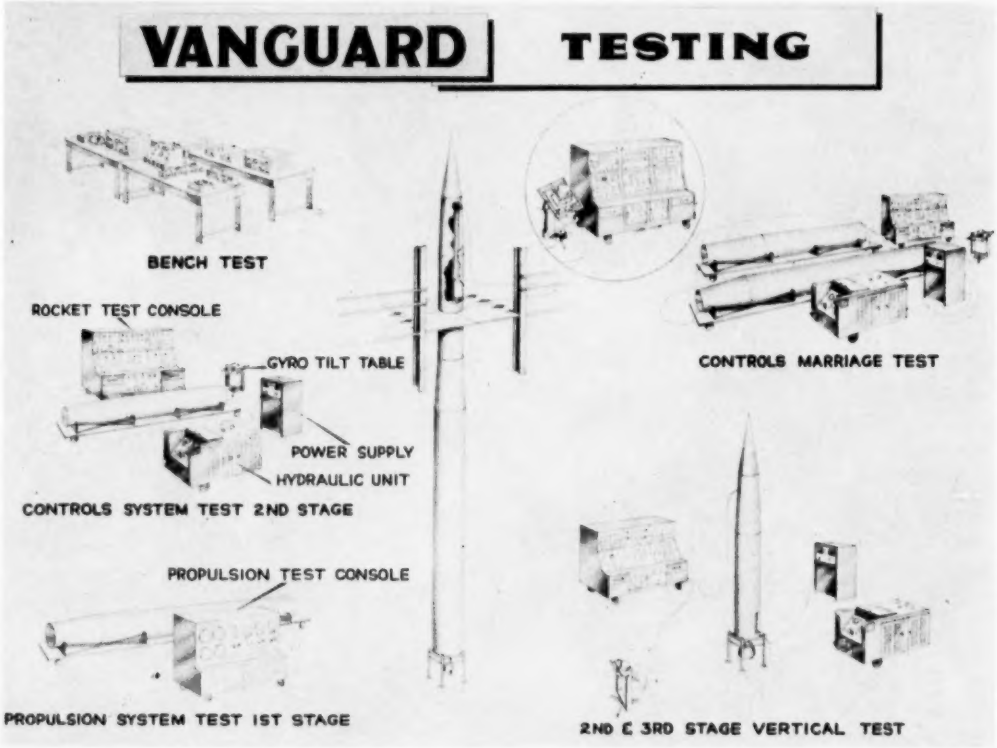
VANGUARD TESTING
BENCH TEST
ROCKET TEST CONSOLE
GYRO TILT TABLE
POWER SUPPLY
HYDRAULIC UNIT
CONTROLS SYSTEM TEST 2ND STAGE
CONTROLS MARRIAGE TEST
PROPULSION TEST CONSOLE
PROPULSION SYSTEM TEST IST STAGE
2ND & 3RD STAGE VERTICAL TEST

Fig. 4.

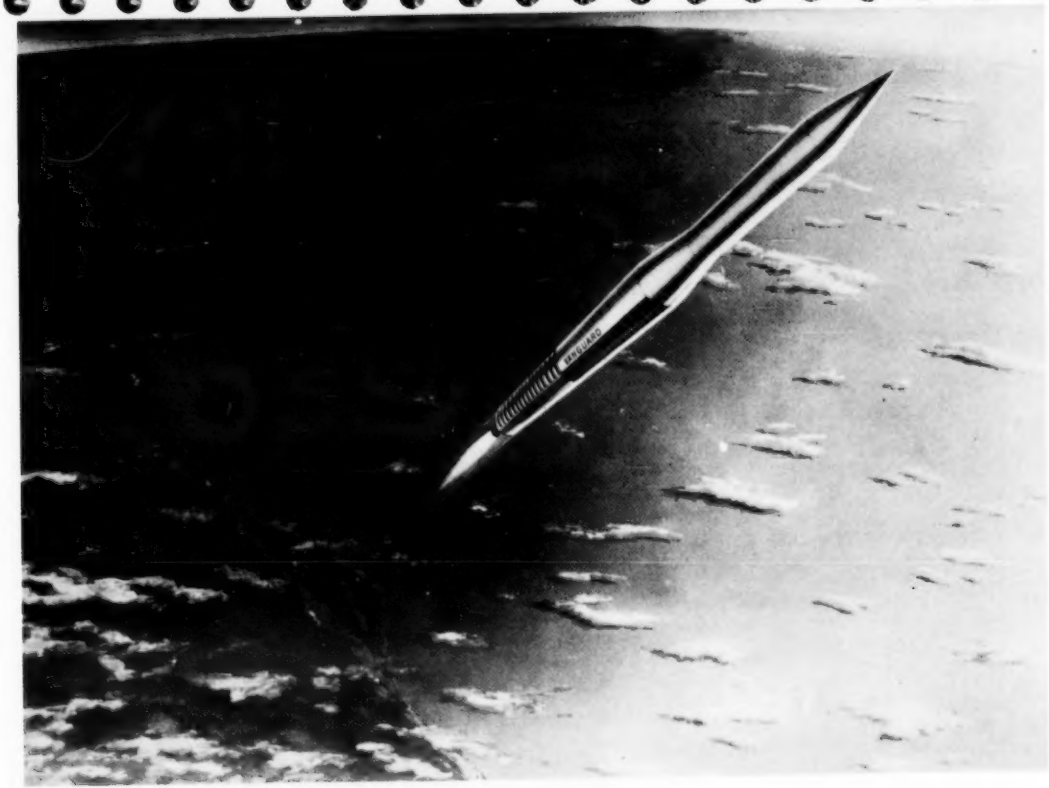

Fig. 5. The Vanguard Vehicle in Flight

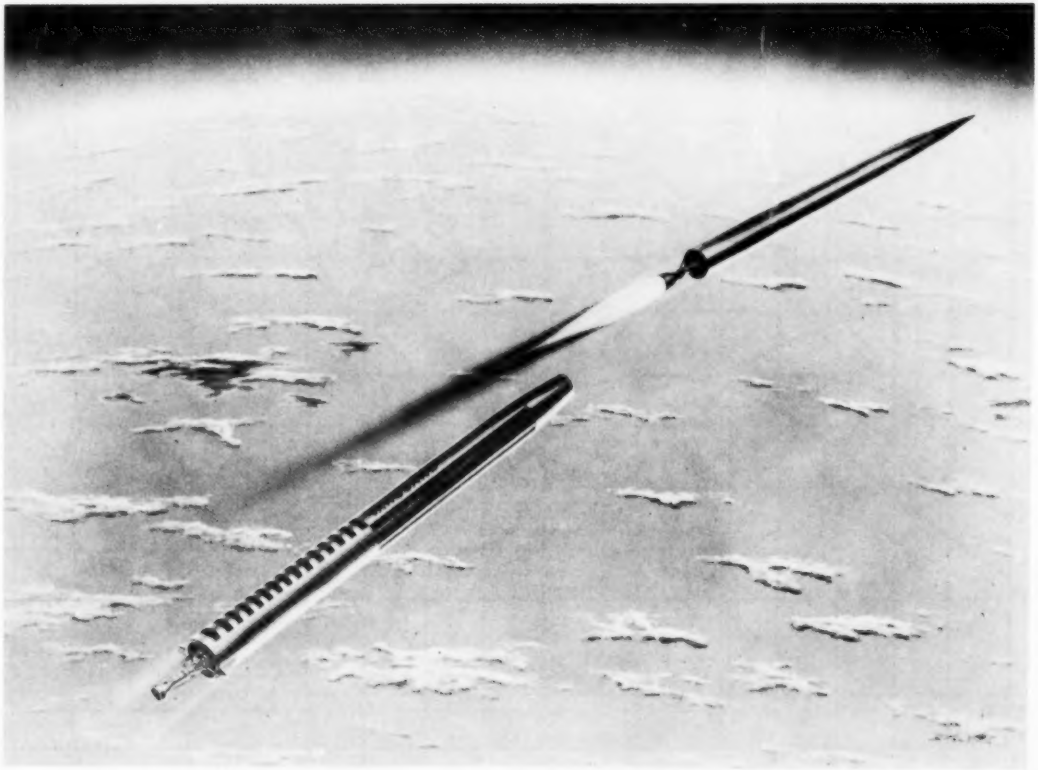

Fig. 6. First-Stage Separation

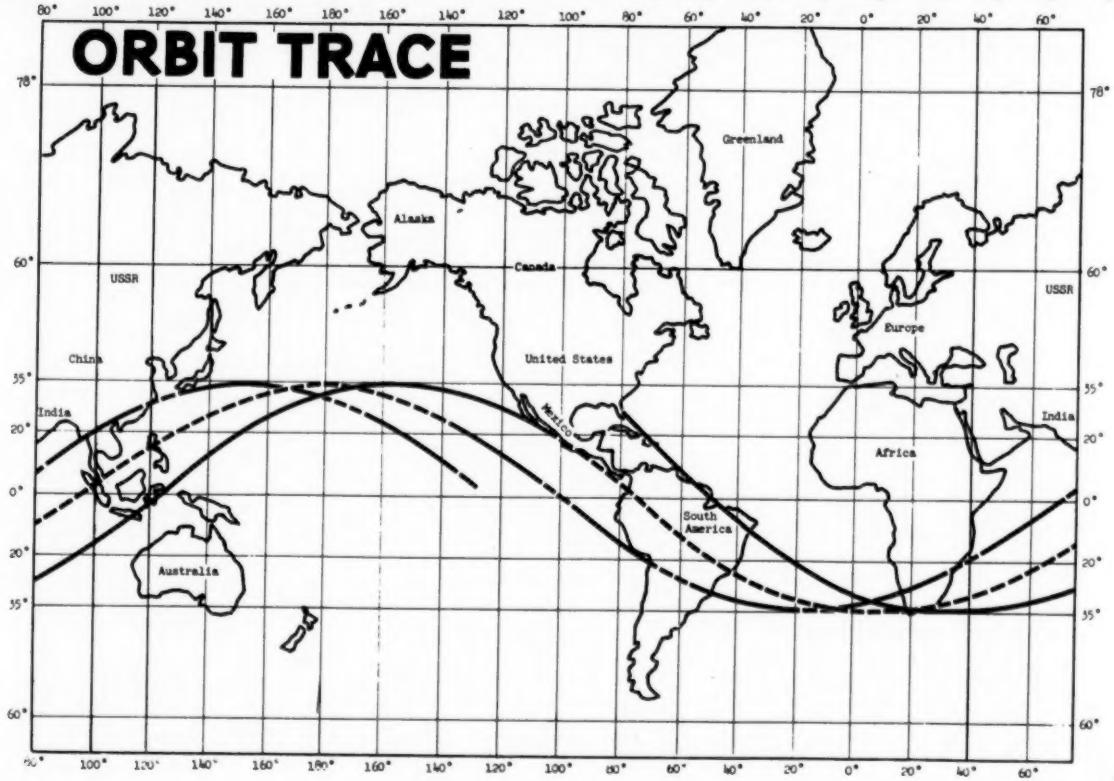

Fig. 7. The Ground Track made by the Satellite

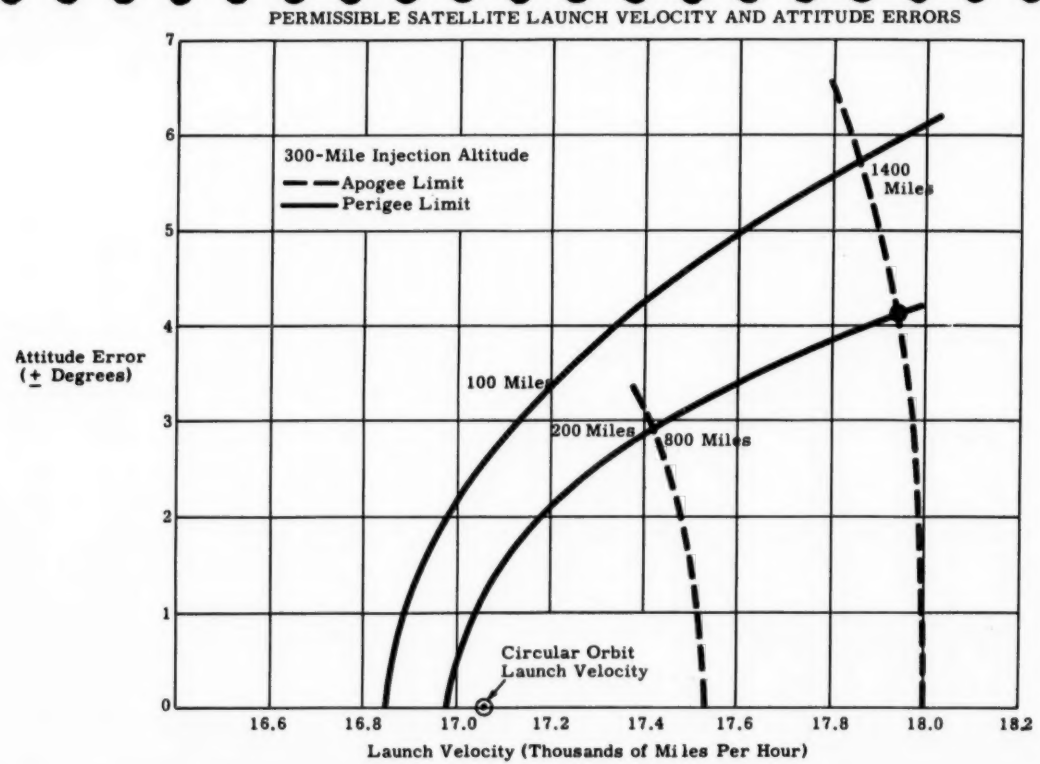

Fig. 8. A Graphical Representation of the Required Velocities and Angular Accuracies

WE SHOULD EXTEND INCENTIVES

Phil Carroll
Professional Engineer

Many of you know that I have worked with incentives continuously since World War I. Thus, I think I can give you most of the reasons why you should keep away from them.

Perhaps the reason most commonly heard is, "Eighty per cent of our grievances result from our incentive plan." Those who say that are tempted to relieve the stresses by throwing out their incentive plans. Many managers have done so. Let me ask you, "Can you solve a problem by running away from it?"

Of course,we prefer to be comfortable. Like the manager who said to me, "Why should I? Remember, I'm due to retire in two years." Or another who said, "Phil, that sounds to me like a helluva lot of hard work." My reply was a question, "Do you know any easy way to make half a million dollars?"

MORE INCENTIVES

Regardless of all the reasons why not, I believe in using incentive plans. Maybe I fit the definition given years ago by George M. Cohan. He said, "A genuine optimist is one who believes in himself despite the facts."

There must be others. Consulting engineers had their biggest year in 1956. Their firms have expanded 650 per cent since their foundings according to a recent survey. (1) In this same vein, I saw seven references to the results of incentive plans in the January 1957 magazines I read. And, it seems to me, I get more inquiries for "good timestudy men" than ever before.

HERE COMES AUTOMATION

You can draw your own conclusions as to whether or not incentives are on their way out. For example, you may agree with the author who writes, "But under automation, with continuous flow, a worker's worth can no longer be evaluated in production units. Hence output incentive plans, with their involved measurement techniques, may vanish." (2)

Maybe they will. But not for the reason given. In the first place, most of the companies we know something about could not utilize automation if they wanted to. Their parts are not uniform enough to run continuously. They would have backyards full of scrap before they could turn off their automatic machines.

In the second place, most companies do not have large enough quantities. We must remember that roughly 86 per cent of our plants have less than 100 people in them.

In the third place, we still have to get some man interested enough to push the button. And to grind and adjust the tools. And to stop the machine when it begins to turn out scrap. We are a long way from the condition depicted in a recent cartoon. The boss man was arriving Monday morning in his limousine at a factory that had smoke belching from the chimneys. His excla-

mation was, "My gosh I forgot to turn off the factory over the week-end."

Those are details. Where that author misses the point entirely, in my opinion, is that incentives apply to people - not machines. Maybe he supposes, like many Industrial Engineers appear to, that incentive plans are suitable only for repetitive direct labor operations. What about the indirect?

PEOPLE SPEND MONEY

Automation is not going to eliminate our overhead. As a matter of fact, if we ever get to automation, all of us will be overhead. And our overhead rates will be at infinity. We will still have salesmen, managers, engineers, accountants, maintenance men, tool makers, and, I hope, timestudy men. Should not we provide incentives for them?

Let's not overlook the basic fact that incentives apply to people. They apply regardless of the type of work done.

At least three are present in most companies. One is negative and two are positive. The three I have in mind are

1. fear - worry lest you catch hell or lose your job
2. pride - desire to accomplish results or to make a name for yourself, attain status
3. hope - urge to get ahead, make more money or to be promoted.

These incentives exist and will continue despite what you and I may think.

DIRECTED INCENTIVE

Thus, the only question about incentive we are concerned with here is whether or not it shall be organized. To answer this question, I'd like to give my reasons why I think we need directed incentives. These I plan to group in three types.

Management decisions
Family comforts
Individual development

Of these, management decisions come first. What products shall we make? What business shall we go after? What prices shall we quote? What deliveries can we promise? These are a few of the fundamental decisions that management must make.

This job of trying to decide today what will happen tomorrow is the manager's most difficult task. Does his organization go along to prove that he was right?

NO SALE, NO JOB

If he is a smart manager, he has set up sales quotas. He must be fully aware of the fundamental so clearly stated as, "No Sale, No Job" - the title of Alexander Heron's recent book. Unless he manages to sell his products, he need not be concerned about incentives either pro or con.

To get customers to buy his output, they were persuaded by someone we call a salesman. What incentive caused him to bestir himself to go out and dig up customers? Maybe the customers came to his plant through jobbers or distributors. What incentives did they have to push his goods?

WHAT IS COST?

Obviously sales effort is not the only factor. Price is important too. Customers buy when they think our price is right. Under our free choice system, they may buy your products or those of your competitors. They may purchase substitutes. They may decide to buy none of these. Thus, to my way of thinking, the customer sets the price.

What they pay us for our products must be more than our costs. Otherwise how are we to survive and prosper? That brings us to the question, "What is cost"? To most of us, cost means Material, Labor and Overhead.

For our purposes, I'd like to have us analyze costs differently. Let's think of costs in only two parts. One is materials - things we, as customers, buy from other producers. The other is conversion - work we do in applying the skills of our organizations. Instead of the term conversion, you may prefer to think of "value added." These terms are not interchangeable. But that is not important here.

The point is that what we do in any plant is to convert materials - change form, shape, size, color. That means work - time and skill of people who make up an organization. Thus, people determine what the controllable parts of our costs are to be.

The time people take to do work depends upon two major factors - method and diligence. Maybe you can improve your methods. Most companies can. Regardless, you still have the twofold problem of

1. Getting people to use the best method available. You know about the farmer who was "not farming half as good as he knows how now."

2. Getting people to work diligently. You know also about the fellow who wasn't afraid of work. He said he could lie down right beside it and go to sleep.

How can managers decide what costs and deliveries are likely to be without some kind of work standards with incentives to meet them?

WORK STANDARDS

Either management sets standards of performance or the people set their own. The difference is important. The excess cost when people set their own standards is about 65 per cent. You get that excess when you divide the most often stated figure of 60 per cent efficiency on "day work" into the cost you would expect at standard. (100 / 60 - 1.0) In amount, that is vastly more money than most companies make as profit.

This 60 per cent efficiency that some experts mention refers to the performance of so-called direct people. Undoubtedly it is much less for the indirect. Here, we are talking about all the people. The efforts of all the people go to make up the bulk of what I call conversion cost.

Therefore, it seems obvious that we should measure the work of the indirect and overhead people. I suggest three reasons. The first is that we have done so little to measure and control overhead costs. As a result, the cost improvements to be realized are tremendous. All of the different kinds of improvements we have made in our direct operations are open to us by studying the indirect. Duplication of effort occurs in many places. We continue to put one system on top of another because of our mistaken notion that systems control costs.

Too, we have all kinds of wasted effort. Lots of work is done over again because there are people to do it. Wasted work goes on because we do not have "blue prints" or specifications for our indirect operations like we set up for manufacturing. Lack of what I call "engineering" is a major cause of excess overhead cost.

Third, and to me the most important, is the need for analyzing how overhead is spent in relation to our several mixed products. Until we make more exact analyses, we cannot establish product costs that remotely resemble the correct ones. Yet, managers must go on making decisions with misleading costs until we can supply better ones.

BUDGETS ARE NOT MEASURES

Expense budgets cannot help us to attain any of these three ends. Budgets, commonly speaking, are only sums of money set up from past performances as stop gaps. None I have seen specify what work should be done for the money allotted. Nor do they limit the number of times the work is to be repeated.

Besides, budgets are set for a function. Production control might be an example. The money allotted is for carrying on the function of production control. But the work required differs widely from one product to another. If any relation of production control to the mixture was considered, it was assumed that the proportions of the past would continue. It rarely does. Customers change their points of view with the weather. Consequently, the budget is too loose or too tight according to the demands for production control brought on by each new product mix.

With these three basic errors, we have no way of knowing that performance is improved when budgets are met. Only last week I saw where a supervisor met his budget for three consecutive weeks and ran over it on the fourth. He had met his budget by putting aside some of the work. When the pile got too high, he was forced to reduce it. His only incentives were fear and pride.

PROFITS LOST

Expense budgets are steps in the right direction. As Peter Drucker says, "Objectives are needed in every area where performance and results directly and vitally affect the survival and prosperity of the business." (3)

All of us will agree with his specification. Yet, except for the urge to make a profit, few companies that I know of have set objectives for every function in their organizations.

Our basic problem is much deeper. It is well stated by G. Charter Harrison. He says, "The outstanding defect of the conventional profit and loss statement is that it. . .reports profits made but it does not show profits lost. . ." (4)

I can add to that from my own experiences. In the few instances where I have analyzed a company's profits, I have found that roughly 20 per cent of the volume was turned out at a loss. This meant something like another 20 per cent of profitable products had to be sold to offset the loss. That tells us whatever profits were made came from about 60 per cent of the volume. All those organizations got from the 40 per cent was the exercise of working on it.

This condition resulted from wrong costs. They were no farther wrong, however, than most company's now are. Does that fact make it clear to you why I think the manager's job of making decisions is so difficult? And Operations Research won't help him very much. He can't get any better answers from the slot machine than he can feed into it.

The solution lies in the correct measurement of saleable output. That and only that is direct labor. All the rest is indirect. We must find out first the equivalent of good saleable pieces because we figure conversion costs as labor plus overhead.

We haven't a chance of getting correct costs until we get a common denominator that measures saleable output. We cannot tell how to correctly direct the efforts of our organizations. Therefore, we should measure work to set the foundation for determining correct costs. Only then can a manager tell where the money is made or lost.

WAGE COSTS

Now let's consider the second group of reasons why I think we need directed incentives. These I called "family comforts." They have to do with our American standard of living. You will note also that they bear directly on the cost of conversion, hence on profits.

People want more money. They are getting more. Some have joined unions expecting to get still higher wages. Along with the higher wages go all of the fringe benefits you know about. Perhaps there are more we have not yet thought of.

For example, look at the want ad columns of any newspaper. There you find the greatest array of advertising for engineers that most of us have ever seen. This is a picture of the customer willing to pay a higher price in order to take the engineer away from some other employer. If the prices paid to get engineers are too high, either the profit disappears or the price of the product goes up. Then the customers may refuse to buy. The only exception I can think of is that you and I, the taxpayers, may continue to buy the output through our Secretary of Defense without immediately knowing we are paying higher prices.

About this attempt to improve our standard of living Alexander Heron says, "The big deal on wages is not the one between the worker and the employer, but the one between the worker and the consumer. The consumer is almost the final judge as to the fairness of the day's pay and the day's work. Both are reflected in the price of the product." (5) And later on, "What can be done to injure sales by raising the cost of a day's work too high can be done just as definitely and just as promptly by making the value of a day's work too low." (6)

Let me restate his comment to fit our topic. "What can be done to injure sales by raising the wage rate of a day's work too high can be done just as definitely and just as promptly by making the productivity of a day's work too low."

Where is this more money to come from? We know there is no gold mine in the back yard to take it from. Thus, as I see it, it must come from two sources - profits and productivity. Much has been taken out of profits already. You see how the per cent of profit has rapidly declined. This may discourage the investor who has money to spare. Occasionally, you see that an attempt to sell stocks and bonds has not been very successful. How then will we get the money to expand and repair our plants?

INCREASED PRODUCTIVITY

That brings us to the real source of our higher standard of living - namely productivity. In this, the most oft repeated definition is "a fair day's work for a fair day's pay." The only exceptions I can remember are two. One is the wish made by one manager who would like to get "a fair day's work for a fair week's pay." The other was the employer in Houston who posted the oft repeated memo concluding with the plea that, "....each employee endeavor to find some time that can be set aside and known as the 'work break'." (7)

To determine what is a fair day's work, I would use timestudy. It is just as suitable for measuring indirect as direct labor. Keep in mind that we are talking about people's costs. And note what Fortune says about our productivity. "Output per employee for all 17 million persons in manufacturing has not increased in the past year. True, the output of the 13 million production workers in factories increased by about the usual 3 per cent. But the number of non-production workers, meanwhile, increased by about 250,000 - enough to cancel this improvement." (8)

By studying the time that people take to do their work, we uncover a lot of wasted effort. In addition, we find out those things that interfere with production. We get down to the foundation of good management. Two pioneers gave us the keys. Frank Gilbreth told us, "Scientific Management hangs upon the science of timestudy." (9) And Henry L. Gantt pointed out, "In connection with the man's record, it is the most complete analysis of the workings of a plant, and the one that will help us most quickly to bring into their proper channels things that have gone haphazard." (10)

MANAGEMENT ERRORS

If we put these two ideas together, we have a sorting device. With it we can sort out the measure of saleable output. To me this is a vital point because today our plants turn out a mix of products. Therefore, as I said earlier we need an equivalent of good saleable pieces as a common denominator before we can hope to get correct costs. For this purpose, Standard time is the best measure we have found to date.

In this sorting, we uncover also what I call "management errors." These I divide into three groups - failure to plan, failure to specify, and failure to follow up.

Failure to plan takes in most of the time leaks we classify as "waiting." Beyond the obvious are all of the bits of waiting time that result from unbalanced work loads, paced operations, and process waiting time.

Failure to specify includes the multitude of indirect elements such as excess stock, poor tooling, and fitting at assembly that destroys interchangeability. There is a much higher percentage of this kind of wasted work in maintenance, tool room, pattern shop, office and engineering because either our "blue prints" are more incomplete or they don't exist at all.

Failure to follow up is the label I apply to that failing most of us have. We issue an order or tell somebody to do something. Most of us are pretty good at starting things. But how many carry out their plans or ideas to successful conclusions. About the only follow up I see that appears to work all the time is the function we call inspection. All the rest seem to be now or then. Perhaps, this is the cause of our many systems.

PROFIT LEAKS

These "management errors" are buried in all unmeasured operations. They should be separated so we know how much they cost. They represent profit leaks. To emphasize this point, let's think of the average profit as being about 5.7 per cent. That means our profits average $5.70 per $100.00 worth of goods sold. Thus, you can see that to plug a $5.70 cost leak any place in your organization has the same constructive result on your P & L statement as to sell $100.00 worth of your products to your customers at 5.7 per cent profit.

Remember too, that "management errors" are wasted time and effort. Therefore, they are indirect labor. As such they cannot earn overhead. This is an important detail. Until these indirect expenses are separated from the so-called direct labor, our overhead costs are misapplied. We make two kinds of cost mistakes. We overcharge one product and undercharge another. That is a direct result of our custom of spreading overhead with a shovel.

Correct costs are a by-product. But a very important one. They help to direct management decisions toward more profitable operations. As a result, people have steadier and better incomes.

The main purpose is to sort out these losses in productivity. My experience indicates that actual waiting time losses run about 10 per cent and extra work

time about 20 per cent. Here then are sources of major improvement in productivity.

Since increased productivity is our only way to improve our standard of living, we need to uncover these time losses. To sort out these leaks so you can see them, you need correct work standards with incentives. These should be based on normal or standard work conditions.

Only then can you have signals that tell you when "management errors" occur. This, in my opinion, offers the most economical and fruitful way to increase productivity. This is the way I suggest we can increase family comforts without adding to inflation.

DEVELOP PEOPLE

That brings us to the third group of reasons why we need directed incentives. These relate to the development of people. We develop people to manage our industries or they fold up. We develop people to turn out our products or we have nothing to sell. Consequently, we need to set goals and measure performances against them. How else can we tell whether or not people are developing?

Rarely do you see any mention of measurement in all this talk about executive development. Can these men develop? Do they? How do we know?

Maybe you agree with Imogene Fey. She says "Of course, America has boundless faith in her young people. She proves it by the size of the public debt she expect them to pay off." (11) I'm sure that you young men agree with James Lincoln. He comments, "Since the average span of life is increasing rapidly, funerals do not occur as often as they should for the best progress of most companies." (12)

Was it security from the cradle to the grave that made America great? Certainly not. It was incentive more powerful than most we have today. It was the chance everyone had to make the most of his skills and abilities.

INDIVIDUAL GROWTH

We still have those skills and abilities. And according to Lecomte du Nouy, the desire to attain a superior level is "....the trait which above all others links man most clearly to the divine task of evolution." (13) And James Lincoln puts it this way. "It is obvious that the Creator in giving to man such abilities expected them to be used." (14)

Besides, we now have much more education to help us utilize our skills. But how do we know we are making the best use of these vital resources?

Unless we measure applied skill and ability, we have only seniority to go by. That can be more disastrous than you may think. Let me emphasize by recalling the startling statement made by Myron Clark, past president of SAM. He says, "It is estimated that less than 20 per cent of the people who are in industry are in that kind of work for which they are best fitted. This means that 80 per cent go to their daily work wishing they were in a different vocation." (15)

Sure, we talk about proper selection and placement. Perhaps, some day we will get the round pegs in the round jobs. Naturally, that will take the brakes off. But how do we get the engine going at top performance?

Experts tell us that most men have a great deal more ability than they ever use. What a loss that is to industry.

What can we do to bring out these abilities? I say, "Let's use incentives." So do others. For example, Business Week reports, "Perhaps the key to General Motors' entire incentive bonus system is that ....every eligible person's performance and qualifications are thoroughly reviewed....each reward is individual...This method of bonus selection cannot be overrated as a force in GM's management development...." (16)

Take another. A survey was made to find out how to get the best from salesmen. It shows that 35 per cent of sales meeting programs included discussions of awards and incentives. (17) And a third says, "....the compensation plan should provide for greater earnings to individuals who are successful." (18)

TOMORROW'S LEADERS

The facts are that people respond to incentives. Whether it's the more money or the improved performance record matters little. People know they are getting ahead. They are getting individual recognition for their output. They have an unbiased measure of their relative worth.

These responses seem vital to me. They counteract the tendency to conform, to go along with the crowd, to hold to the average. They offset the trend toward mediocrity.

My belief is that we need incentives that induce people to go beyond "keeping their noses clean." We need performances that are better than hanging on until the pensions start. We have to encourage people to stick their necks out to be counted. How else will we get the leaders for tomorrow?

EXTEND INCENTIVES

Keep in mind that industry is people - not machinery and buildings. Industry succeeds or fails depending upon the people who make up what we call its organization. What is the difference between success and failure?

My guess is that is is not difference in skill. I believe the skills are about the same. If that is a reasonable assumption, then the difference between success and failure lies in the application. Then what is it that gets people to apply the skills they have? You may say, "Leadership." Isn't that incentive?

No incentive I know of can equal the potential of inspiration. Even so, one expert has said that only 10 per cent of those who succeed do so through inspiration. Then also, how much of the leader's inspiration can we expect will get the desired actions from the people who are shielded by one or two layers of interposing supervisors?

Make no mistake. There is no system you substitute for good management. But management that is good is a decision-making group of men. Their decisions have to be carried out to be of any value. How do we get the necessary action?

Again I say, "By directed incentives." Many companies direct their manager's interests toward making profits by means of incentives. To make profits, however, these manager's must first get salesmen to bring in the customers. Second, they must get people to control costs and to make deliveries.

To get the customers, many companies direct the interests of their salesmen toward attaining their quotas by using incentives. Also many companies direct the interests of their supervisors toward controlling costs through the use of incentives.

Note carefully, however, that it is the individual who does the work that makes the sale or makes the cost. Supervisors control the circumstances or environment, if you prefer.

Only the person who does the work can turn it out correctly - or with defects. Is he interested in doing it correctly and efficiently? Does he conserve or waste materials?

With sound incentives, you can gain and sustain his interest in higher productivity of good work. Incentives provide the flywheel that helps make come true more of management's decisions. That's because the individual has a financial interest in the outcome.

Through incentives we gain higher productivity. That is what made our Nation great. Through incentives we gain also higher earnings and lower costs. Incentive is the only management tool that will give us all three of these constructive benefits. To me, these are reasons enough why we should extend incentives.

With incentives, we can get the individual to apply more of his inherent abilities.

And finally, Directed Incentive is the best antidote I know of for the attitude that Winston Churchill pointed out. He said, "We must beware of trying to build a society....where enterprise gains no reward...." (19)

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INCENTIVES - PRO AND CON
THE CON POSITION

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While my part in this debate is the con position, let me be the first to admit that incentives are worthwhile - in their proper place. My position is probably best described as a "yes - but" one. Incentives are worthwhile but what do we use in areas where incentives can't be used either because we lack the means to measure or the contribution of the operator is too small. I'd like to review the tools available to management, through Industrial Engineering, to accomplish savings when these conditions prevail.

Before we get into these areas, I must first discharge my duty of taking the con position relative to incentives.

There are many negative opinions on the value of incentives, the following being a list of some of the more common problems associated with them.

1. High cost of administration, especially when changes in the operation or product are made.
2. Systems are usually difficult for workers to understand.
3. They are a restraint to change.
4. There is difficulty experienced when part of the plant is on incentive and part not.
5. Not all work can be accurately measured in terms of production units.
6. Work available to operator is not unlimited.
7. System tends to shrink jobs rather than enlarge them to provide greater job satisfaction.
8. Supervisors use the system as a "silent supervisor" and become lax.
9. Employees become time and money oriented rather than in doing a good job.
10. Supervisors spend too much time explaining compensation.
11. Quality of material and work varies making measurement difficult.
12. Ability of employees to "beat the system."
13. Employees hold down production so that base rate will not be changed.

14. The system fails to share the benefits of increased production properly.

15. The attitude of unions toward incentives is generally not favorable.

16. Supervisors, particularly first line, do not understand the system.

17. Additional grievances.

18. Safety record suffers.

19. Difficulty in determining a fair day's work.

A debate can be based on any one of these points -- and I am sure we haven't covered them all. In addition, as no two systems are alike, they all have different strong and weak points making it difficult to generalize or to say that incentive systems are no good for the following specific reasons.

Rather than take a negative approach and try to beat down incentives, let's take a positive view and see what avenues are open to the Industrial Engineer to reach the goal sought by an incentive system.

The goal of incentives, as I see it, is to increase production without incurring a corresponding increase in cost. Incentives can achieve this goal when the individual on incentive is in control of the situation. Incentives on hand work are fine, even on semi-automatic operations where the operator's effort is directly relatable to the final output.

But what about situations where the operator is not in control - what measurement system do we apply? This situation of an employee having little control over an operation is one that is and will become even more important as mechanization is applied to more operations. There is also the problem of measuring the contribution of certain activities such as service units, staff people etc. An Industrial Engineering Dept. can affect cost savings in both these situations if it will gear itself along the lines of -

1. Designing good layouts and equipment.

2. Designing good measurement systems.

3. Conducting operations analysis studies.

These three areas offer opportunities to achieve savings for the company on a much broader scale than incentives. Many of the activities can be conducted simultaneously and at no higher cost than that of operating an incentive system. Let me develop these three areas more fully.

DESIGNING LAYOUTS & EQUIPMENT

This area of Industrial Engineering is concerned primarily with equipment and layout and can be divided into the preventative (new installations) and the corrective (existing installations). While most Industrial Engineering organizations prefer to work with the former, the bulk of their activity is concerned with the latter. In either case there are three subdivisions:

1. Building Design - Industrial Engineering should be responsible for the interior design of buildings such as warehouses, offices, laboratories, and factories. These designs can achieve savings by standardizing on dimensions so that stock steel, stock window arrangements, stock partitions, and Modular office and laboratory equipment are used.

2. Equipment Selection - Industrial Engineering should select new and improve existing equipment to make it run at higher speeds and greater efficiency, and or do things the machine was not originally designed to do. It is in this field that Industrial Engineering plays its part in mechanization.

3. Equipment Arrangement - Industrial Engineering should arrange equipment to achieve the best flow of material, the best handling of material, etc.

In all of these areas Industrial Engineering can achieve savings of considerable proportions - savings that can be justified in a short period of time yet accrue additional savings in succeeding years without additional pay-out.

DESIGNING MEASUREMENT SYSTEMS

The second area open to Industrial Engineering to achieve savings is in designing good measurement systems.

Whereas in the first area we were concerned with equipment and layout, in this phase we are primarily concerned with the measurement of various activities and the resultant utilization of manpower and equipment.

This area should be primarily concerned with the following eight activities:

1. Establishing standards - These can be in production, process and maintenance and concern factors such as manpower, yields, waste, etc. The techniques used in this area consist of visual observations [redacted], work sampling and statistics. Industrial Engineering can do itself and the company a lot more good by spending time in the field and

making visual observations of specific operations that need improving rather than developing some highly theoretical way of doing it. This might be construed as a "nut and bolt" approach to engineering, but the bulk of the dollar savings can be achieved quicker and cheaper in this fashion.

2. Measurement of effectiveness - There is need, particularly in staff and service areas, to have some measure of the worth of a function -- to determine the contribution by the function. As in the other areas, the Industrial Engineering group can achieve dollar savings by setting up measurement criteria against which these organizations can be measured.

3. Materials handling - In addition to the specific installations handled by the layout people, Industrial Engineering can do much by creating an awareness by all production people and also staffs, such as Purchasing, Traffic, and Marketing of the need to consider material handling in their activities. This is a case of getting many experts planted in the field, and if you have 500 such experts, their individual contribution does not have to be too great before the aggregate amounts to a considerable sum.

4. Systems and procedures - Here savings can be achieved by reviewing such things as the order processing system, possibly cutting the number of copies, eliminating all filing, etc. The whole area of paper work can be reviewed to see if we can eliminate some of the staggering amount of activity that comes under this heading. Another area that Systems and Procedures can tie into is electronic data processing.

5. Organization Planning - Here is an area that few Industrial Engineering organizations pay enough attention to, yet it is right in their baliwick. While we are concerned with standards and the numbers of people involved, not enough attention is paid to the organizational arrangement of these people. Organization Planning should be given more consideration by Industrial Engineering.

6. Planning and Scheduling - Industrial Engineering has been active in setting up schemes for Production Planning and to a lesser extent in Maintenance Planning. Further attention to the latter will eliminate the need for incentive system in this extremely difficult area to measure.

7. Fatigue Measurement - Particularly in areas where there are heavy work and difficult working conditions involved, the development of measurements of this sort will be invaluable as an aid in determining the number of people to be used in operations, the design of rest stations, determining rest periods, equipment justification, etc.

8. Continuous Attitude Surveys - The development of attitude surveys that are of a continuous nature rather than on a spot basis will be of great help to the company. Savings can be made by preventing work stoppages, eliminating bottlenecks, etc.

This area, measurement and the utilization of manpower and equipment, is most closely associated to incentive systems because of the standards and work measurement. All of the 8 activities suggested as part of this area offer savings, and the establishing of realistic standards alone can achieve savings equal to or exceeding those realized by an incentive system.

OPERATIONS ANALYSIS

Here we are concerned with all areas of Industrial Engineering. The techniques of applying mathematics and statistics to problem solving are applicable, at least in our experience, to production, inspection, marketing, inventory, and I hope in the not too distant future, major management decisions. The savings to be realized can be attractive. The 3 areas that seem most fruitful are:

1. Statistical Evaluation - The application of statistical techniques to existing data to detect underlying relations and regularities, or to establish levels of accuracy or significance; and the use of probability or risk analysis in evaluating alternate decisions involving different chances of success.

2. Design of Experiments and Surveys - Planning the collection of data to obtain the greatest amount of desired information under given limitations of money, personnel, or equipment, and to get data in a form capable of simple and unambiguous interpretation. Also the determination of the number of measurements or the size of a sample to be taken to obtain required assurance of quality or accuracy.

3. Design of Control Systems - The study of complex and interrelated activities with respect to their critical aspects, such as quality, cost, price, service, etc., and design of new or improved methods of operation, generally involving -

   (a) Construction of quantitative or mathematical descriptions (models) of operations, and identification of critical variables or characteristics.

   (b) Determination of the values to be assigned to these variables to obtain best over-all performance.

   (c) Study of alternate "models" to select those having the most desirable operating characteristics.

The use of these techniques, either on independent assignments in the company, or in conjunction with the Layout and Manpower & Equipment people, has great potential. In its simplest form, operations analysis has always been practiced by the Industrial Engineer. He has always considered alternate courses of action, but now the addition of mathematics and statistics adds a new dimension to his considerations. This tool, properly used, can do more for Industrial Engineering than the establishment of incentive systems because it considers a larger whole. If incentives claim a 30% savings in production, what effect does it have on inventories, marketing, production, scheduling, research experiments? Some, I'll agree, but minor. Operations analysis on the other hand can have a distinct effect by setting formulas for inventories, developing market research experiments, developing production scheduling techniques, and establishing research and quality control data experiments. The savings to be gained in these fields should more than equal a 30% production saving.

Summary

We have looked at the Con side of incentives - and taken a quick side step to look into other areas open to the Industrial Engineer to effect savings. The areas suggested were Layout, Manpower & Equipment Utilization, and Operations Analysis. Subdivisions of these form a check-list of Industrial Engineering activities.

NEW TECHNIQUES IN PRODUCTION MANAGEMENT
(abstract)

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The fundamental operating problems in the management of industrial production may be said to consist of a class of decisions relating to:

1. acquisition of production facilities
2. allocation of facilities to products and sub-products
3. setting of production rates
4. establishment of lot sizes for purchase or manufacture
5. time scheduling of purchase orders or lot production for parts, sub-products, and products
6. establishment of inventory levels
7. product pricing.

Ideally, these may be considered to represent continuing decision problems requiring joint solution with the objective of, say, maximizing profits. The solution to this problem requires finding a preferred compromise between sales revenue, production cost, and inventory cost in the face of uncertainty with respect to each of these and subject to restrictions on such resources as facilities, time, and capital. Although the complete solution to this overall decision problem is still far from attainment, Operations Research techniques have been developed for treating various individual aspects and parts. Certain of these techniques will be illustrated and their limitations and significance discussed.

ARE WE GOING OVERBOARD WITH COST FIGURES?

I. Wayne Keller
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Several months ago news reports featured a story of a guided missile which went out of control and disappeared into the mountains of New Mexico. The reports mentioned that elaborate control devices had been built into the missile and had been tested thoroughly before the launching. But, despite all of the controls and tests, there was a failure for some unknown reason. In contrast there were numerous unreported successful flights in which the controls worked. It is imperative that the percentage of failure be brought to a practical minimum. National defense is serious business. There is no room for any appreciable margin of error. Because of this the scientists in charge of guided missile projects would answer the question, "Are you going overboard with controls?" in the negative. Missiles are too expensive, too powerful, and too fast to be directed by the sensory perception of man. Automatic electronic controls are essential to their effective use.

In contrast, let's turn back the pages of history from the atomic age to the stone age. Here too we find missiles — rocks heaved by cave men. Control of the missile was provided by the strength and skill of the thrower. If he had an adequate supply of rocks and could throw more accurately, further and harder than his adversary he survived. If he couldn't, there was a new head man in the cave.

From the cave-man's rocks to guided missiles we have a succession of improvements in the control features of weapons. The faster and the more powerful the missile, the greater and more complex the devices required to control it. And, it is to be noted that there have been more developments in this field in the last ten years than in all of the other years of recorded and unrecorded history. Need has stimulated invention and each development has led to others in geometric progression.

In much the same fashion, new developments have been made with great rapidity in the field of cost control. So much so that the question is now raised, "Are we going overboard with cost figures?" The answer is "No" if the cost figures are required to operate our businesses effectively and minimize the possibility of failure. It is "Yes" if the cost figures are impeding rather than aiding the successful management of a company. Returning for a minute to missiles, the one which went astray was reported to have dual circuits. Possibly some further reduction in the possibility of failure could be achieved with triple circuits. This advantage must be weighed against the added cost and the reduction which the added weight would cause in the speed and range of the missile. So it is with cost figures. They must be adequate but there is a practical limit beyond which the returns diminish rapidly.

Today's need for figures has been created by the tempo and complexity of modern business. Fifty years ago, yes even twenty-five years ago, the cost figures found in most companies today would have been regarded as excessive by all levels of management from presidents to foremen. Management then was not in the stone-age of figures but it was in the little-black-book age. A few significant figures were all that they needed to supplement their personal observations as bases for their decisions.

A few years ago I was going through some of the files of old records of the Armstrong Cork Company. In one packet dated 1895 were the quarterly financial statements for that year submitted by the chief auditor to Mr. Thomas M. Armstrong, who was then president of the company. With these was a well-worn notebook in which Mr. Armstrong had recorded quantities of raw material purchased, production by types of corks, and sales dollars by months for each plant and branch. Beyond these data he probably relied upon his observations during his frequent trips through the three factories to keep himself informed on the operations of the business.

In my early years with the company I had personal contact with notebook control methods. At that time I was helping to install a cost system in one of our older factories. I found that every foreman in that factory carried a little book in which he noted labor and production statistics. Despite the engineered standards and budgets, and the system of variance reports which we developed, they refused to abandon their notebooks. It was rather discouraging to see them refer to these rather than to our reports when they were discussing costs with the factory manager. If they had been asked, "Are we going overboard with cost figures?" their answer would have been a resounding "Yes", probably emphasized by certain strong expletives. Today that factory, with some of the same foremen still on the job, is doing an outstanding job on cost control and cost reduction. All of the little black books have disappeared. The variance reports of twenty years ago have been expanded, daily cost control data have been added, and special cost studies are made frequently. Notwithstanding, the plant controller is under constant pressure to supply more operating data.

Why has this change taken place? The answer is found in our comparison of the cave-man's rock and the guided missile. The character of the business has changed. Even within the area of each foreman's responsibility it has become too complex and fast moving for him to rely primarily on sensory perception to guide him in his control of costs. Manual labor has been replaced by high-speed machines, cork and other natural raw materials have been replaced by numerous synthetic materials which are combined in complex and ever changing formulations, and a simple line of cork products has become a complex line of products each designed to meet a special need of an industry. Add to these a substantial increase in volume and "change" is an understatement.

This change in this one plant has also occurred throughout the Company. In 1895 Mr. Armstrong had three plants and one sales organization to administer, and total sales were about $2,000,000. Today our president, Mr. C. J. Backstrand, has eighteen plants, seven sales divisions and four subsidiary companies under his responsibility with a total sales volume of about $250,000,000. The expanding volume of our company is not unique in American industry. New businesses are being formed every day. Small companies are growing into larger companies, and even the largest are growing in dollar sales volume if not in unit volume. A business is dynamic, not static. It either grows or stagnates and ultimately fails. Its success or failure is determined to a major degree by its cost figures.

The earliest uses of costs were for accounting purposes. In the fourteenth century Italian merchants were using double entry bookkeeping and keeping inventory accounts.(1) They charged to inventory values not only the purchase cost of the merchandise, but also for taxes on it and

costs of weighing and unloading. Only by including appropriate costs in inventory values were they able to determine profits for interim periods before a venture was completed. This procedure was essentially the same as the accounting principles of inventory valuation today, except that we have attempted to state the kinds of costs which should be included. As manufacturing enterprises developed accounting procedures were adapted to bring conversion costs into inventory values and this required the determination of production costs per unit. A comparison of the production costs of different periods marked the beginning of cost analysis and gave some impetus to cost control.

Now, moving from the fourteenth and fifteenth centuries to the beginning of the twentieth century, we find managers becoming dissatisfied with actual unit costs. It was difficult to explain reasons for changes in costs and there was no way to measure efficiency. These inadequacies were the catalysts which started the present industrial engineering and cost accounting techniques. If management had been quite satisfied with the data available for decision making the techniques of Taylor, Gantt, Bedeaux and Harrison would not have been received so readily. Standards and standard costs were developed to meet a need for better controls in an increasingly competitive and complex business climate. As with control devices for weapons, there have been more developments in cost control procedures in recent years than in all of the other years of economic history.

Have we gone overboard? I would say emphatically that we have not. I would also say that even more profitable developments lie ahead and most businesses are far from the point of diminishing returns from cost figures.

We will not devote any more time to discussing cost figures for accounting purposes. Basic principles and techniques are well established. Modifications of these are being made from time to time as the need arises, such as the use of the lifo method of inventory valuation or the change from absorption costing to direct costing in recording non-variable expenses. But these are different applications of the figures rather than basic changes in the figures themselves or in the accounting purposes for which they are developed.

It is in the use of cost figures to provide management guidance in decision making that we find opportunities for new and better techniques. Not too many years ago a standard cost accounting system which provided monthly variance reports showing deviations from standards by areas of responsibility was considered to be quite modern. It permitted management by exception in that attention was directed to those areas where costs were above standard. However, two major weaknesses exist in such a system. First, the reports are too late to be of value in cost control and second, the emphasis is on short-range rather than on long-range planning.

Costs must be controlled before they are incurred. A variance report shows only the degree to which they were controlled. It does indicate steps which should be taken to avoid a repetition of failures in the control processes. But even for this purpose the time factor usually has an adverse effect. At best variance reports are completed within ten days after the close of a month. By that time foremen have new problems — changes in production schedules have been made, possibly different products are on the production line, different materials or at

least new lots of the same materials are being used, temperature and humidity conditions have changed with the movement of the calendar, and so on. In short, the parade has passed and a new one has been formed and is already passing in review. To analyze prior performance requires foremen with excellent memories or a very elaborate set of supporting data developed on a daily basis during each month. The former is the exception rather than the rule. The latter is defensive rather than corrective.

If time and effort are being devoted to compiling daily historical data they can be used much more effectively in operating pre-incurrence control procedures. To do this it is necessary to change the commonly accepted concept of when costs are incurred. We usually think of them as being incurred while production is in process. It is then that raw materials are used, labor is expended in conversion, and expenses are being applied to the products. But, most of the management decisions which will affect the total cost of a plant, if not the costs of specific products, are made some time before production begins.

Raw materials represent one good example of costs that are incurred by management decision before production starts. The cost is incurred when a purchase order is placed. True, if the material is not usable it can frequently be sold and some salvage value recovered. But the costs of placing the order; of receiving, inspecting and storing the material; paying the invoice; setting up the inventory records; and accounting for the transaction can never be recovered in the sale of the material as part of a finished product. Neither can the difference between cost and salvage value be recovered. And, if it can be sold, there is some expense in disposing of it.

With the customary agreements that at least some hours of pay will be given if a man reports for work and there is no work for him, labor costs are incurred when the men ring their clock cards. In fact, labor cost incurrence actually goes back to the time men are hired. These labor costs arise from unemployment compensation insurance determined by experience rating and from supplemental unemployment compensation agreements.

Expenses, for the most part, are incurred by management decision long before they are applied to products produced, or charged against profits of the period as "unabsorbed." For example, salary costs are incurred when management decides upon the number and position grades of supervisory, staff and clerical salaried personnel. Rent is incurred when a lease is signed. Depreciation, insurance and some taxes are incurred when a decision is made to replace or expand buildings and equipment. Demand charges for power are incurred when the line is connected and then are frequently changed by the peak requirements in some prior period. Preventative maintenance costs are incurred when the maintenance program is established. Supply costs, like those of raw material, are incurred when the purchase orders are placed.

Effective control requires the direction of management attention to the time when costs of material, labor, rent, depreciation, etc. are actually incurred and management must then accept the premise of controlling them before they are incurred. If a missile is to hit a moving target the control devices must detect the speed and direction of the target and fire the missile to the point where the target will be and not to where it is when the missile is dispatched. Likewise, cost control

must provide for similar lead time. Control procedures operated before costs are incurred will provide greater assurance of meeting standards in the production processes.

If the concept of controlling costs before they are incurred is firmly established in a company the favorable effect upon its profit is tremendous. The key to such control lies in organized future production plans based on the anticipated ability to sell a product over the next year and the next five or ten years. Appraising the future, planning for optimum profit under the conditions anticipated and then controlling operations so that the plans are realized, encompass the entire function of management.

This concept of control raises the question of our ability to predict product, industry and general economic trends. Forecasting is a unique combination of economics, history and judgment. However, many companies have demonstrated their ability to forecast rather accurately, within limits of plus or minus five percent. Such accuracy is achieved only when the forecasting process is a continuing rather than a periodic one. In my opinion an ideal process is one which predicts monthly figures for the current quarter, quarterly figures for the following three quarters and annual figures for the next five years. Each quarter such a forecast is revised, the past quarter is dropped and a new quarter added. At the close of each year the past year is dropped and another year, four years hence, is added. Cost and profit planning then becomes a process of applying current income and cost data to the anticipated sales levels and modifying them for forecast changes.

Any forecast, and any control processes require detailed data. These are readily available if standards and flexible budgets are in use. The standard units of each major raw material per unit of finished product can be applied to the forecast production to develop a usage budget by types of materials. This, modified by planned changes in raw material inventories, will show the purchasing problem for each period of the forecast. This permits purchasing plans to be made which will result in the most favorable raw material prices. If existing sources are indicated to be inadequate new sources can be developed before the situation becomes critical. Research can be directed toward developing alternate materials, and the desirability of vertical integration to produce some raw materials will be indicated.

With detailed continuing forecasts labor requirements can be established by numbers of men and skills. The data will show when overtime should be used to meet temporary peak demands and when new employees should be hired to meet indicated permanent increases in volume. With the labor requirements forecast by jobs or skills training programs can be developed so that properly trained personnel will be available when needed.

Facilities requirements simply cannot be established without long-range forecasts. Since such a large portion of factory expense is related to the capacity to produce, rather than to the actual production activity, no small part of the pre-incurrence control of expense is directly related to the planning of production facilities.

Long-range planning based on continuing forecasting determines the cost control strategy. The tactics of cost control are securing the most effective utilization of costs after they are incurred but before they are applied in the production processes. This is accomplished through the

correlation of production schedules and standard allowances. When a foreman is given the production schedule for his department it should show the costs, in units not dollars, which he should have for the scheduled production. For example, a production schedule for molded plastic parts, such as electrical equipment, should show the machine on which each part is to be made, the standard number of pieces per machine hour and the standard machine hours for each molding press. With these data would be shown the allowable number of press operators, and hours of machine set-up time, material transfer labor, clean-up labor, and routine maintenance labor. Quantities of molding material allowable for the number of each part scheduled for production should also be shown as well as the allowed percentage of scrap. With this information in hand the foreman of the molding department will know what his allowances are before production is started. He can then plan and control his cost units intelligently.

However, plans are of no value if the objectives are not achieved. Checks must be provided on the extent to which material, labor and expense are being utilized effectively to produce the quantities of saleable products established by the standards. Daily or even shift reports should be prepared in the department which show the allowed and actual cost units for the period. Time should not be lost in sending the data to a central office for processing and for the preparation of reports. The schedules of the department show the standard allowances. The records of the department, ultimately required for inventory record and labor payment purposes, show the actuals. It is a simple matter for a clerk in the department to note the standards and actuals on a report form which is kept in the department for constant reference by the foreman.

With pre-incurrence control of costs and current tabulation of the degree of control achieved the variance reports simply confirm and summarize results which are already known. They provide guidance for plant and general production managers and become a part of the integrated reports of a company. Until our cost figures have been carried beyond the pre-incurrence cost control processes we have not gone overboard with cost figures.

The industrial engineers and controllers, working in close cooperation, have contributed much to scientific management through the development and use of standards. The predetermination of costs and their comparison with actual results is now generally accepted practice. However, there are some companies which have not adopted these techniques and are limping along with actual costs. Pre-incurrence control is only recently beginning to be accepted. There are many opportunities, which have been tested and proven, for further advances in the uses of costs in these control processes. Beyond these lie relatively new procedures which are now only in the development stage.

Operations research is an outstanding example of these techniques which are being developed. Here entirely new opportunities are being presented to teams of industrial engineers, controllers, and other scientists and management personnel for the use of cost figures. In operations research we have the correlation of data and the formulation and solution of business problems from mathematical models not unlike those used in guided missile research. With this technique it is possible to evaluate the many variables in a management problem and arrive at the optimum answer. The increasing use of electronic computers in business will accelerate the development of operations research. Cost figures are the raw material of operations research, for the objective of management is the realization of optimum profit and optimum profit is the

direct result of the optimum relationship of income and costs.

The managers of large businesses have recognized the inadequacy of sensory perception in providing bases for their decisions. The very size of the companies would have brought about this realization even without the constantly accelerativaly rate of change in economic conditions and competitive situations. The managers of many small businesses have not recognized the need for control data. In too many instances they are still relying upon their personal observations in making their decisions. Probably that is why there are so many "small business" problems. Instead of meeting these through modern management processes small business is seeking special tax concessions, special financing considerations and even special regulatory measures. The success of small business will not be assured by measures which establish uneconomic competitive relationships. It will be assured by sound management based upon adequate control data. Cost figures are as essential to the success of a small business as they are to that of a large business. Problems and their solutions are the same in any business, the only difference is in the number of digits in the figures. Until we have reached the point in any business at which cost figures hinder rather than aid in the realization of optimum profit we have not gone overboard in cost figures. Should we strive for perfection in our development of cost figures? Yes, for unless we strive for perfection we are not likely to achieve adequacy.

(1) Origin and Evolution of Double Entry Bookkeeping - Edward Piregallo

A MINIMUM TOTAL COST APPROACH TO THE CONTROL OF DISTRIBUTION INVENTORIES

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In recent months, company managements all over the country have been reviewing their inventory levels more intensively. The primary stimulus to this study is the shortage of cash in many businesses. Because money is difficult to obtain, managements are reviewing the way in which the capital they have is being utilized. Inventory is a prime candidate for study because businessmen tend to look upon inventory as a non-productive asset constituting a drain on resources.

Fortunately, in the last five years, scientists and engineers have made considerable progress in the study of inventory systems. A review of this progress reveals that new analytical approaches are available which provide practical answers to inventory problems in the ever increasingly complex business environment. It is now possible to accurately determine the results received from a dollar invested in inventory.

The purpose of this paper is to describe a method of determining finished goods inventory levels in a national distribution system. This method is based on the notion of minimum total cost of operation. For this purpose, total cost of inventory operation includes the cost of inventory depletion or stock runout as well as the resupply and inventory carrying costs commonly considered.

An actual case example will be used to indicate how the minimum cost of operation concept is applied. This case example concerns a complex national distribution network with several factory producing points and over 50 field warehouses located throughout the United States. The case study deals with inventory determination at field warehouses and will indicate:

(1) The criteria for measuring and evaluating the performance of the existing inventory system.
(2) The considerations involved in selecting the type of system.
(3) The approach in developing a minimum total cost system.
(4) The significant factors in operating the minimum total cost system.
(5) A comparison of the minimum total cost system with other systems of inventory control.

But first, what motivated management in our case example to study inventory?

MOTIVATION FOR INVENTORY STUDY

This company became interested in inventory study because of the

same factors motivating most companies to study inventory. First, an expanding sales volume was requiring a higher and higher capital investment in inventory. The company began to doubt whether these valuable capital dollars were fully productive. Second, although the important function of inventory in providing delivery service to customers was fully recognized; there was some question as to what was the most economical level of customer service and what level of inventory was required to provide the proper level of customer service.

Another factor motivating management to study inventory was the rising cost of carrying inventory. One example of this increased cost was the fact that warehouse space cost had risen 25% in a five year period. Also, the usual complaint of the sales department asking "Why are we always out of stock?" influenced management to review the existing inventory system.

CRITERIA FOR REVIEWING THE PRESENT SYSTEM

Basic to study of an inventory system is a clear, simple statement of the function of or objective in having inventory. The system should be evaluated in its ability to accomplish this objective.

The primary purpose of field finished goods warehousing is to provide normal and emergency service to customers. This is expecially true when a company's products compete largely on the basis of service rather than price, design, or quality.

However, it is practically impossible to provide 100% service to all customers at all times. Such 100% service would result in uneconomically large inventories. The notion of an inventory stocking policy based on a calculated, expected risk of runout is becoming a well accepted management practice.

From this line of reasoning, the objective of finished goods inventory in field warehouses can be stated as follows:

To provide adequate customer service at economical cost levels.

In the case study, the ability of the existing system to meet this objective was evaluated. The existing system employed a constant 30 day stock level as the order point, and 75 day stock was used as the order quantity. These values were used regardless of warehouse location or item sold. Analysis revealed that this system failed to meet the inventory objective in not considering the variability of the following factors:

(1) Demand - sales patterns vary considerably between items and a constant 30 day order point failed to provide adequate or consistent customer service.

(2) Lead time to procure replenishment stock varies by warehouse location and producing factory - thus, a constant 30 day

order point failed to provide adequate or consistent customer service.

(3) Ordering costs, inventory costs, and depletion costs vary with the individual item and the warehousing location - thus a constant 30 day order point and 75 day order quantity resulted in inconsistent costs of operation at the various warehouses.

Thus, the existing procedure failed to meet the objective of providing adequate service at economical cost levels.

Another point to consider in reviewing a given inventory system is the extent to which actual operation corresponds with the prescribed system. In cases where operating people fail to follow the prescribed system the reason is frequently a weakness in the basic system design for which the operating people are making what they feel is appropriate compensation.

This was apparently the situation in our case example. A comparison of the actual inventories levels with the inventory levels that should result from the prescribed system was made on a sampling basis. These studies were designed to both measure inventory levels intensively at several typical warehouses and also to sample several typical items system wide. The results indicated the actual inventory was approximately 50% higher than would be expected. Interviews with warehouse personnel indicated that the reason for such non-conformance was due to a lack of faith in the prescribed system. However, in adjusting for deficiencies in the prescribed system, local warehouse people were apparently over-compensating. Also both formal and informal adjustments took the form of using increased order quantities rather than increased order points. As will be seen later, this had the effect of decreasing the amount of stock depletion in the most expensive way.

In summary, study showed that the existing situation was inadequate on two counts.

(1) The basic system design failed to meet the objective of field warehouse inventories.

(2) Operating personnel failed to follow the prescribed system and were making adjustments in the most expensive way possible.

SELECTING AN INVENTORY SYSTEM

Selection of an inventory system should, of course, reflect the objective of the system. In the case example the objective was stated as: "Provide adequate customer service at economical cost levels." This objective can be reworded to require the one best system as follows: "Determine the inventory procedure that relates customer service and inventory costs in such a way as to maximize the profits of the enterprise.

Using this objective as a criterion the two basic types of systems should be evaluated:

(1) The fixed order point and constant order quantity system is the most common system employed. The fixed order system is also referred to as the minimum-maximum system or the X, Y system (X for order point and Y for order quantity). In this system a stock replenishment order is initiated whenever the stock on hand plus the amount on order becomes equal to a minimum or X level. The amount ordered, Y, is a constant amount.

The fixed order system is generally used where lead times are short and perpetual inventory records are available to give immediate notice that X, the order point, has been reached. Under these circumstances this system results in the minimum cost of operation.

(2) The fixed order time system or s, S system also finds common use. In this system stock position is periodically reviewed - say the first of each month. If the inventory level is below an amount small s, a quantity sufficient to bring inventory to the amount large S, is ordered.

The fixed order time system is frequently used where perpetual inventory records are absent, the order time corresponding to the date of periodic physical inventories. The system also finds use where lead times are long or where orders flow directly to production and regular periodic scheduling is desirable. When lead times are short, perpetual inventory records are available, and a regular time of ordering is not important, the fixed order time (s, S) system is more costly than the fixed order point (X, Y) system described above. In the case example, short lead times exist, perpetual inventory records are available, and the requirement of a regular ordering time is absent. Thus, the fixed order point system will result in the lowest cost for a given level of protection and thus is the type of system that best satisfies the objective. The problem that now remains is to design the specific system of the X, Y type. In approaching this problem an examination of the basic factors inherent in an X, Y system is essential.

FACTORS INVOLVED IN THE X, Y SYSTEM

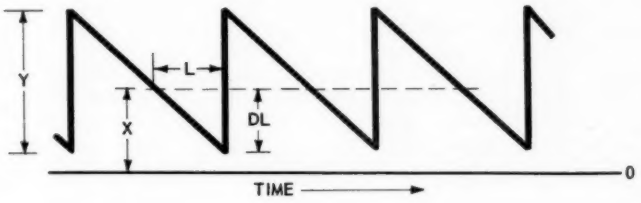
Several factors should be considered in the design of an X, Y inventory system. Although these factors are commonly understood, a summary is appropriate before proceeding on.

Lead time and daily demand are two of the factors involved. This is demonstrated in Figure 1 which is a graph of the X, Y inventory

system. In Figure 1, the distance above the horizontal 0 line represents the inventory at a given time. As time progresses to the right, sales are made at a rate D per day and inventory decreases along the sloped line until the reorder point X is reached.

FIGURE 1

GRAPH OF X, Y INVENTORY SYSTEM



It takes L days after reaching the order point until replenishment stock is received. During this lead time L, the daily demand D continues and inventory decreases to a point D times L (DL) below the X point before resupply arrives.

X minus DL is the low point in the inventory cycle. Stock can run out at this low point and unsatisfied customer demand occur. Thus, the lead time L and the daily demand D are important factors in determining the order point X in the X, Y system.

The reorder frequency is another factor involved. The effect of reorder frequency on the inventory system is shown in Figure 2.

FIGURE 2

EFFECT OF REORDER FREQUENCY

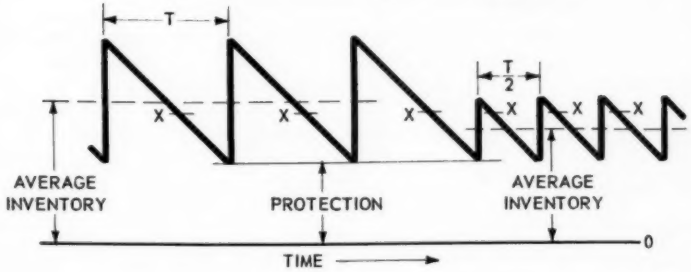


Figure 2 shows two groups of inventory cycles both of which have the same daily demand D (slope of the line), the same lead time L, the same order point X and the same protection against runout. However, the cycles to the right have double the reorder frequency (half the cycle length) of the cycles to the left. It is noted that changing this factor alone has a significant effect on the average inventory level. The cycles to the right with more frequent reordering have a reduced average inventory.

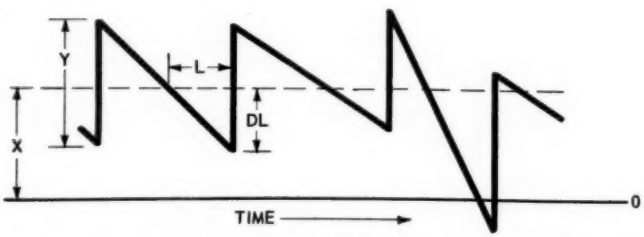
Thus, the frequency of reordering is another factor to consider in designing the X, Y system.

The variability of demand is another factor involved. In figures 1 and 2 a constant daily demand was shown by the steady slope of the line. If such a demand existed the X point could be selected so that stock ran out at the exact time the replenishment stock was received. This would place the troughs or low points right on the 0 line in Figure 2.

However, demand (sales) is variable on a daily, weekly and monthly basis. The effect of demand variability is shown in Figure 3 below.

FIGURE 3

EFFECT OF VARIABLE DEMAND



In Figure 3, the effect of variable demand is shown by varying the slope of the line. Note that the stock level stays above the 0 line until an extreme demand occurs. At this time stock runs out and the customer demand is unsatisfied. Thus, the variability of demand is another factor involved in the design of the X, Y system.

Three factors affecting the inventory system were described above. These were lead time, variable demand, and frequency of reordering. Three cost factors are also involved.

(1) Cost of Resupply - cost that occurs whenever replenishment stock is ordered.

(2) Cost of Carrying Inventory - cost that is proportional to the size of the inventory.
(3) Cost of Depletion - cost that occurs when the customer demand is unsatisfied due to an "out of stock" condition.

The six factors described above are interrelated. For example, more frequent ordering (smaller Y order quantity) was seen to reduce inventory, thus lowering inventory carrying costs. However, more frequent ordering increases the costs that occur each time orders are placed. Similarly, the cost of runout can be eliminated by selecting an order point that is higher than any conceivable demand that could occur during lead time. A zero cost of runout could be achieved but at the expense of a high inventory carrying cost. Thus, all the above factors are interrelated in their effect on the X, Y system.

The objective of inventory planning was stated as "Provide Adequate Customer Service with Economical Cost of Operation." An inventory system that minimizes the total of ordering cost, inventory carrying cost, and the cost of runout (cost of not giving customer service) accomplishes the objective and should tend to maximize the profits of the business. Thus, the approach is to develop the inventory system that minimizes resupply inventory, and depletion costs. The next section describes the development of such a system.

SOLVING THE PROBLEM WITH THE MATHEMATICAL COST MODEL

The factors to be considered in designing an X, Y system were described above. A formal statement of the problem can now be made:

Determine X (Order Point) and Y (Order Quantity) Such That The Total of Resupply Cost, Inventory Carrying Cost, and Depletion Cost is a Minimum Considering the Lead Time, Size and Variability of Demand.

A mathematical model has been developed which expresses total cost in terms of the factors involved. The step by step development of the model will be described in as nonmathematical a fashion as possible. This development is as follows:

Resupply Cost

The cost of resupply is the cost incurred each time a replenishment stock is ordered from the factory. The total cost of resupply is composed of two types of costs - fixed costs and costs which vary with the order size.

Fixed resupply costs are incurred through order handling and editing at the warehouse, the central office, and the factory. These costs are fixed per order processed and will be designated by the symbol C_O.

Costs that vary with the size of the order make up the variable resupply cost. These are costs such as transportation and material handling. Variable costs can be expressed as an amount K per unit on the order. The cost for any order is expressed by K times Y the order quantity. Thus, the total cost of ordering is:

$$C_O + KY$$

All costs in the model must be expressed on an equivalent time basis - daily, weekly, or monthly. A cost per day basis was selected. Resupply cost occurs once per inventory cycle. The number of days in the cycle equals the order quantity Y divided by the average daily demand D, or $\frac{Y}{D}$. Then, daily resupply cost is found by dividing $C_O + KY$ by $\frac{Y}{D}$ giving:

$$\boxed{\frac{C_O D}{Y} + KD}$$

The enclosed term is the expression for daily resupply cost to be used in the mathematical model.

Inventory Carrying Cost

The second cost factor is the cost of carrying inventory. This cost will also be expressed on a daily basis in terms of the related factors. Inventory carrying cost is the product of two factors - the daily cost of carrying an item in inventory and the average number of items in inventory.

The cost of carrying an item in inventory is the sum of several individual costs.

1. Expected return on investment
2. Warehouse rent
3. Taxes
4. Insurance
5. Obsolescence

A portion of the annual sum of the above costs can be related to an individual item. This value will be designated by the symbol C_I. Expressed on a daily basis, the cost of carrying one item in inventory is $\frac{C_I}{K'}$, where K' is the number of working days in the year.

A term for the average number of items in inventory can be developed by averaging the peaks and troughs in the inventory cycle shown in Figure 4, below.

FIGURE 4

AVERAGE INVENTORY

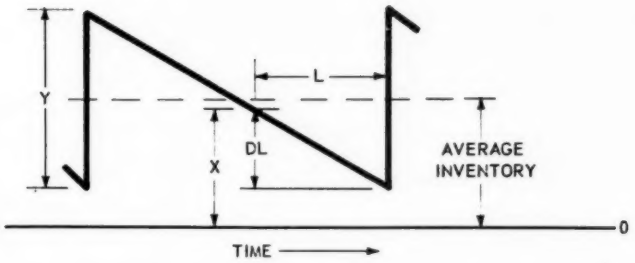


Figure 4 shows that the average inventory point can be located by starting at X (order point), subtracting DL (demand during lead time) and adding one-half of Y (order quantity). The following expression results:

$$\text{Average Inventory} = X - DL + \frac{Y}{2}$$

However, the low inventory point in the cycle is not always X − DL as shown in Figure 5, below.

FIGURE 5

EFFECT OF DEPLETION ON AVERAGE INVENTORY

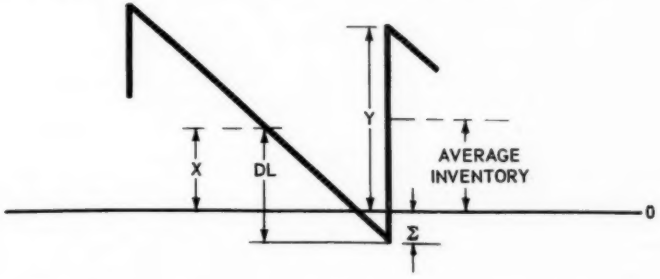


Figure 5 shows an inventory cycle in which runout occurs. Since inventory can't be less than zero, the low inventory point in Figure 5 is X − DL + Σ. The term Σ is defined as the expected number of items demanded in excess of X during the lead time and will be discussed in greater detail subsequently. Thus, the expression

for average inventory should include the average runout as follows:

$$\text{Average Inventory} = X - DL + \Sigma + \frac{Y}{2} \ *$$

The final expression of the daily cost of carrying inventory is the product of the daily cost of carrying one item and the average number of items.

$$\boxed{\frac{C_I}{K'}\left[X - DL + \Sigma + \frac{Y}{2}\right]}$$

The enclosed expression will be used in the inventory cost model.

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* This development of average inventory is based on desired small runout percentages where X is greater than DL. A more general and precise development of the expressions being developed is included in a technical supplement at the end of this paper.

DEPLETION COST

The third cost factor to be considered is the cost of depletion or stock runout. This cost is incurred whenever demand for an item cannot be supplied from inventory. This cost may take the form of good will, extra effort in recapturing a customer, or the loss of profit on a sale that might have been made. The precise determination of this and other cost factors is described in a later section.

Depletion cost is the product of two factors - the daily cost of being short one item during lead time and the expected number of times an item is short. The cost of depletion can occur as a lost sale or as additional order handling, communication, and transportation expense in filling a customer's order from another location. The total of these costs as applied to the shortage of one item will be designated by the symbol C_S.

Depletion costs are experienced during the lead time period which occurs once per inventory cycle. A daily depletion cost can be obtained

by dividing C_S by $\frac{Y}{D}$, the number of days in the cycle. Thus, the daily cost of being short one item per lead time is:

$$\frac{C_S D}{Y}$$

The expected number of items short during a lead time period can be expressed as:

$$\sum_{i=1}^{\infty} iP_{X+i}$$

This term which will represent the expected number of items that will be short with a given X (order point) considering the lead time, and the distribution function of the demand. The importance of obtaining an accurate, adequate description of the statistical nature of the demand will be discussed in a later section. Thus, the final expression for cost of depletion is the product of daily cost of one item short per lead time and the expected number of items short.

$$\boxed{\frac{C_S D}{Y} \sum_{i=1}^{\infty} iP_{X+i}}$$

The enclosed expression is the third and final term in the cost model.

TOTAL COST MODEL

Addition of the three costs (developed above) into one long term gives an expression for the total variable cost of operating the inventory system.

$$C_T = \underbrace{\frac{C_O D}{Y} + KD}_{\text{Resupply Cost}} + \underbrace{\frac{C_I}{K'}\left[X - DL + \sum + \frac{Y}{2}\right]}_{\text{Inventory Carrying Cost}} + \underbrace{\frac{C_S D}{Y} \sum_{i=1}^{\infty} iP_{X+i}}_{\text{Depletion Cost}}$$

There are two unknowns in the above expression - X (order point) and Y (order quantity). The other terms, ordering cost, daily demand, inventory cost, lead time, etc. are all characteristics of the present situation that can be measured. Thus, the total cost model is a tool for analyzing the effect that different X's and Y's have on total cost. It is recalled that the objective in formulating the total cost model was to determine the X and the Y that would give minimum total cost of inventory system operation for a particular item in inventory. The X and

Y that give such minimum total cost are found by taking the partial differential of the total cost equation with respect to both X and Y. The resulting equations set equal to zero provide two equations as follows:

$$Y = - \frac{\frac{K' DC_S}{C_I} \frac{d\Sigma}{dX}}{1 + \frac{d\Sigma}{dX}}$$

$$Y^2 = \frac{2K' DC_O}{C_I} + \frac{2K' DC_S}{C_I} \sum$$

With known values of the parameters K', D, C_S, C_I, C_O, and for the probability distribution of demand during lead time, P_{X+i}, the X and Y that provide the minimum total system cost of operation can be calculated. * The X's and Y's so determined for each item in the inventory provide an optimum policy.

These equations have been solved for a wide range of the above mentioned parameters and the results have been both tabled and graphed.

A typical table is shown on the following page. In order to use the table the following information must be available for each item:

1. Demand
   - A. D. = Average Demand during Lead Time (D. L.)
   - V. D. = Standard Deviation of A. D. times Skewness Factor when demand during lead time cannot be approximated by normal distribution. **

2. Costs
   - C_O = Cost of Resupply
   - C_I = Cost of Carrying Inventory
   - C_S = Cost of Depletion

3. Lead Time
   - L = Lead Time

The inventory analyst, armed with the above information, would select the table headed with range for A. D. and V. D. for the item under study. Then with the ratios C_O and C_S computed, he would read off the

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* Different techniques have been worked out for the solution and plotting of the results for these equations. See unpublished work of C. E. Clark, Booz, Allen & Hamilton, and C. J. Ancker, Jr., Applied Research, Inc.

** See Technical Supplement for method used in determining skewness factor.

TABLES FOR DETERMINING
ORDER POINT (X), AND ORDER QUANTITY (Y)
A. D. = 25 to 29.9
V. D. = 30 to 39.9

$\frac{C_1}{C_2}$

		.01 - .039					.04 - .069					.07 - .099					.10 - .199					.20 - .25				
			A. D.	V. D.	$\frac{C_1}{C_2}$	$\frac{C_0}{C_2}$		A. D.	V. D.	$\frac{C_1}{C_2}$	$\frac{C_0}{C_2}$		A. D.	V. D.	$\frac{C_1}{C_2}$	$\frac{C_0}{C_2}$		A. D.	V. D.	$\frac{C_1}{C_2}$	$\frac{C_0}{C_2}$		A. D.	V. D.	$\frac{C_1}{C_2}$	$\frac{C_0}{C_2}$
.01 - .049	X	39.2	1.62	.15	892	-130	63.1	1.56	.91	296	-132	72.0	1.56	1.23	189	-130	77.4	1.46	1.44	96	-127	87.0	1.38	1.87	70	-120
	Y	30.8	.10	.73	-27	270	30.0	.10	.72	-43	297	28.7	.07	.63	-27	310	27.9	.05	.60	-15	313	26.4	.10	.60	0	317
	r	16.7	-.6	.5	-437	-8	4.6	-.2	.2	-70	0	2.5	-.1	.1	-27	0	1.7	-.1	.1	-9	0	.8	0	0	-5	0
.05 - .099	X	33.6	1.55	.10	891	-74	57.8	1.54	.92	300	-70	66.8	1.46	1.24	183	-66	72.3	1.44	1.44	97	-66	82.0	1.34	1.78	70	-62
	Y	41.6	.52	.58	10	186	41.9	.41	.62	-27	200	41.1	.41	.59	-23	202	40.4	.41	.56	-13	206	39.1	.40	.51	0	210
	r	16.4	-.4	.5	-422	-8	4.7	-.2	.2	-70	0	2.6	-.1	.1	-27	0	1.8	-.1	.1	-10	0	.8	0	0	-5	0
.10 - .149	X	29.9	1.50	.03	891	-52	54.3	1.46	.84	306	-44	63.5	1.46	1.17	183	-46	69.0	1.38	1.36	99	-44	78.9	1.32	1.70	70	-40
	Y	50.9	.75	.51	33	150	51.9	.65	.58	-23	146	51.2	.63	.55	-17	160	50.7	.62	.54	-11	160	49.6	.62	.50	0	160
	r	16.0	-.4	.5	-408	-6	4.8	-.2	.2	-70	0	2.7	-.1	.1	-30	0	1.8	-.1	.1	-9	0	.9	0	0	-5	0
.15 - .199	X	27.3	1.44	-.03	890	-36	52.1	1.46	.80	303	-40	61.2	1.44	1.10	187	-34	66.8	1.44	1.30	101	-32	76.9	1.32	1.65	70	-30
	Y	58.4	.86	.49	30	126	59.3	.84	.51	-3	144	59.2	.83	.55	-17	136	58.7	.82	.52	-11	136	57.6	.78	.49	0	136
	r	15.7	-.4	.4	-396	-6	4.9	-.2	.2	-70	0	2.7	-.1	.1	-27	0	1.9	-.1	.1	-10	0	.9	0	0	-5	0
.20 - .499	X	25.4	1.41	-.08	890	-23	50.1	1.44	.74	312	-21	59.5	1.44	1.06	190	-20	65.2	1.38	1.26	102	-19	75.4	1.30	1.61	72	-18
	Y	64.7	1.05	.46	60	94	66.5	1.00	.55	-17	97	66.0	1.00	.53	-17	99	65.5	.98	.51	-11	99	64.4	.94	.47	0	100
	r	15.4	-.4	.4	-386	-4	4.8	-.2	.2	-70	0	2.7	-.1	.1	-27	0	1.9	-.1	.1	-10	0	.9	.0	0	-5	0
.50 - .999	X	18.6	1.36	-.27	890	-11	43.7	1.38	.56	327	-11	53.5	1.36	.89	197	-10	59.4	1.32	1.09	106	-10	70.0	1.32	1.45	72	-9
	Y	92.9	1.60	.40	93	65	95.7	1.54	.51	-3	66	95.6	1.52	.52	-13	67	95.2	1.52	.50	-7	67	94.5	1.46	.48	0	67
	r	14.3	-.4	.4	-350	-2	4.8	-.2	.2	-67	0	2.8	-.1	.1	-30	0	1.9	-.1	.1	-10	0	.9	0	0	-5	0
1.00 - 1.50	X	13.0	1.36	-.34	890	-7	38.4	1.36	.40	330	-7	48.3	1.36	.73	203	-7	54.4	1.34	.94	111	-7	65.5	1.30	1.29	72	-6
	Y	125.2	2.26	.36	120	62	126.8	2.20	.49	7	58	129.0	2.18	.49	-7	58	128.8	2.18	.48	-6	58	128.2	2.18	.48	0	58
	r	13.1	-.3	.4	-310	0	4.8	-.15	.2	-67	0	2.8	-.1	.1	-27	0	2.0	-.1	.1	-11	0	.9	0	0	-5	0

$\frac{C_0}{C_2}$

values for X, Y and r from the table. For example, if A. D. = 25; V. D. = 30; $\frac{C_O}{C_I L}$ = .15 and $\frac{C_S}{C_I L}$ = .10 the analyst would record

X = 66.8; Y = 58.7 and r = 1.9%. The data appearing to the right of these results in the table are unit interpolation figures for values above the convenient base figures illustrated.

The analyst then records the Order Point as 67, the Order Quantity as 59, if no restriction concerning lot sizes are involved, and also an expected percentage depletion of 1.9%. The percent depletion advises the warehouse manager that he should expect to be faced with situations of not being able to deliver this item to the customer from stock in about 1.9% of the situations. This does not mean lost sales in this amount since the resourceful warehouse manager still has the possibility of obtaining permission from the customer for a deferred delivery, or he can "refer" the order to the nearest warehouse for shipment.

Operation of the System

Order points and order quantities may be determined centrally and preprinted on warehouse inventory cards. This has an advantage over the common practice of having the warehouse manager recompute the levels periodically. Quite often this simply just isn't done or is not done accurately. In this system it is almost imperative that the levels be determined centrally since cost and lead time information must be collected centrally. Also, if it is desired to advise the warehouse manager of expected percent depletion, this can also be recorded on the card.

This is often useful information to give to the warehouse manager in place of the usual instruction - "you are never to run out and you must keep the inventory levels down."

Since the warehouse manager will have participated in determining the percentage of referrals and deferrals he normally can convince his customers to accept under depletion conditions, the percentage depletion can serve as a realistic control percentage, enabling the warehouse manager to communicate with the central office on a quantitative basis when asking for review of his situation. In fact, a rather unexpected reaction occurred during one installation of this system. Local warehouse managers when being told about the system, how it was designed and how it would affect them were favorably impressed. One manager commented, "I don't understand the mathematics of this system, but I can see that you have at last got an approach which takes into account our problems in regard to customer service." This was in reference to the inclusion of the depletion cost in the total cost of the equation and the information he received concerning expected runout percentages.

System Maintenance

It is evident that the system requires periodic review of the demand and cost values. Experience to date has indicated that new X. Y.'s computed quarterly using the most recent six month sales data are satisfactory. The cost terms may be recomputed annually since these costs do not vary radically over a short time. As will be seen subsequently, lead time is an important determinant of inventory levels. Therefore, continuing sample studies of actual lead times should be made. Measures that can be taken to reduce this lead time will substantially reduce inventory investment. Clerical and order routings for central office review should be critically examined in this regard. A sample study shown in Table I computed from the tables described earlier and showing the effect of reducing lead time by 2 and 4 days illustrates this point.

TABLE I

EFFECT OF REDUCTION IN LEAD TIME

Sample of 20 Items in Warehouse A

Lead Time		Inventory Investment		Total System	Variable Costs
Days	Reduction	At Cost	% Reduction Over Present	C_T*	% Reduction Over Present
14.1	present	$23,301	—	$2,959	—
12.1	2 days	$21,783	6.6%	$2,878	2.7%
10.1	4 days	$19,419	16.7%	$2,716	8.2%

* C_T = Order Costs + Carrying Costs + Depletion Costs as computed from Total Cost Equation and put on an annual basis.

This study indicates two ways in which the effect can be measured, namely Inventory Investment, and secondly, what we shall refer to as "Total System Variable Costs." The first comparison, Inventory Investment, is a familiar one and is seen to be quite important since it represents the amount of capital freed for other investment. Based on a sample of 17 items chosen at random, it is noted that inventory investment can be reduced 6.6% if the average lead time can be reduced 2 days, and 16.7% if 4 days can be eliminated from this replenishment time.

The second comparison, Total System Variable Costs, is made by computing and summing the individual terms in our total cost equation. This is performed for the two different lead times. In many respects this is a more meaningful comparison since it includes return on investment and balances it against ordering, depletion and other variable carrying costs. This should therefore represent reduced operating expense (assuming that all actions indicated by any change in the individual cost factors are actually taken - including actually reinvesting money freed by lower inventory levels) and is a measure of the expected effect on pre-tax profit. In this small example 4 days reduction in lead time would reduce Total System Variable Cost by 8.2%. In a company having in the neighborhood of $10,000,000 invested in inventory this can be worth from $100,000 to $150,000 per year and should be an incentive for study and control of lead times.

It should be noted that this system is based on the principle of extrapolating past demand performance as the basis for determining the order point and order quantity to be used as guides for the ensuing three months. Where significant seasonal or growth trends are present, these must be taken into account in inventory planning. Where such trends can be forecast on an item basis and represent only minor changes in level from one three month period to the next, a simple adjustment in the average demand, A. D. proportional to the forecast should be sufficient.

Factory finished goods stocks may be affected in an interesting way as a result of the introduction of this system. Where factory schedules are determined by always having on-hand or on-order from a production plant a given number of months of sales of a given item, a problem may arise in actually obtaining the benefits of reduced warehouse inventories. If the experience factor - say 4.2 months on hand and on order - is not modified, reduction in warehouse inventory will merely result in increased factory finished goods stock. An appropriate adjustment in the experience factor can be determined and should be made early in the installation, particularly if significant inventory reductions have been indicated in the warehouse inventories.

RELATION TO ELECTRONIC COMPUTERS

In these days of increased application of electronic data processing and high speed communications equipment, attention to the tools of system analysis is often ignored or given only cursory attention. Where the basic method of decision making is automated without first making certain that the best, or at least a better system is employed, there is a real danger of investing in a rather expensive computer program that one may be reluctant to change. This rush to "automate the confusion" may well saddle management with less than the best decision making system.

For these reasons, it is generally advisable to consider the design of the inventory system and select the most economical system for the particular company's needs before making a computer feasibility study or replacing existing procedures with electronic automation. This is not to argue against the desirability of quick attainment of clerical savings but rather to bring out the point that analysis and selection of the most appropriate system as a first step may avoid the needless confusion of two separate programming, installation, education, and training jobs upon management and clerical personnel.

The tables and graphs of Order Point and Order Quantity discussed here were developed for use during the pilot installation of the system. In considering an electronic application, the tables would not generally be programmed into the memory of the computer. Rather, the computer can be more economically programmed to make the basic calculations each time and the apparent complexity of the system poses no serious, or expensive problem. The value of an integrated system, tying in the calculation, maintenance, control and reporting aspects of the system into one program offers substantial clerical and programming savings.

The tables developed do have a utility that is important. With knowledge of the various costs and demand statistics for estimating the resulting inventory investment and the total system costs. In this way a means is provided for estimating savings and for comparing different systems.

EXPECTED RESULTS AND COMPARISON WITH OTHER SYSTEMS

An important question that should be asked of a more elaborate, albeit refined, system concerns the improvement resulting from its application. If the system does not produce better results in some manner then it is obviously not worth installation. If it is a more costly system then the results should be sufficient to make the system worthwhile.

There are often conflicting criteria for evaluating the efficacy of a given system to produce results. Thus the question, in what ways may systems be compared?, needs to be explored. There are essentially two major ways in which inventory systems may be compared. There is also a third point, that while essentially already included in the first method of comparison, is worth of special consideration. These three points of comparison are as follows:

(1) Required Inventory Investment in Dollars at Standard Cost
(2) Total System Operating Costs - the sum of Ordering, Carrying and Depletion Costs and
(3) Stock Availability Factor - or Expected Runout Percentage.

The effect of item three is already included costwise in item two but in companies that stress good customer service this factor deserves independent consideration.

In order to make such a comparison of systems one would like to have a powerful analytical method which would be capable of simultaneously considering all the ways in which inventory systems can vary and also include the complexity of costs and demand that have varying characteristics for different items and locations. No such method exists. So, for the purpose of providing an empiric evaluation of different proposed systems a sampling study was made. While this does not have the power of the desired more general method, it should give a realistic picture of the merits and costs of the various systems.

Before making this comparison, it should be stated that existing inventory may be at the level it is at because of two factors - 1) the degree of enforcement or control in accordance with the system as designed or 2) as a result of the system design itself (that is, the inventory policy itself and the rules by which ordering is guided determine levels which may be considered the "standard" for that system). Therefore, since any given situation has both elements of control and of design operating, the actual levels depend in a complex way upon these two factors. Therefore, any comparison that is made must include a way of factoring out human compliance in regard to the basic design in order to show the effect of the system design.

Table II is designed to bring out the following comparisons of what are called four different "systems."

I. Actual System - This represents the actual inventories for 17 sample items in two typical warehouses. The basic policy is a 30-75 day policy and the levels shown indicate the combined effect of control and design.

II. The 30-75 day Policy Enforced - if complete control were practiced regardless of runout. This represents approximately 52.5 days of inventory for each item.

III. Least Total Cost System - Here the inventories and costs have been computed from tables illustrated herein.

IV. Economic Order Quantity System - The classical system for determining Order Point and Order Quantity was used to compute the levels. In this system

$$Y = \sqrt{\frac{2K' C_O D}{C_I}}$$

X = Highest monthly demand of past six months times $\frac{L}{30}$.

Examination of this table discloses several important facts. First

TABLE II

INVENTORY SYSTEMS COMPARISON

Comparison of Results from 3 Different Inventory Systems with Actual Inventories*

System Number	Warehouse	Average Yearly Costs: Ordering Cost	Carrying Cost	Shortage Cost	Total System Cost	Average Inventory Investment: Units	Dollars at Cost	Average Runout Percentage
	A	490	4395			126,975	49,401	
I	B	375	1030			28,865	9,078	
Actual	Total	865	5425			155,840	58,479	
II	A	429	2287	1048	3764	58,038	26,225	11.3%
30-75	B	427	1194	2768	4389	12,446	10,491	17.1%
Policy	Total	856	3481	3816	8153	70,484	36,716	approx. 12.6%
III								
Least	A	538	2028	393	2959	56,127	23,301	2.75%
System	B	382	1858	435	2675	21,284	16,228	2.77%
Cost	Total	920	3886	828	5634	77,411	39,529	approx. 2.75%
IV								
Economic	A	724	1819	670	3213	48,020	20,914	4.0%
Order	B	505	1720	925	3150	22,730	15,066	7.1%
Quantity	Total	1229	3539	1595	6363	70,750	35,980	approx. 5.2%
IIIa Least System Cost (without skewness correction)	A	602	1719	715	3036	49,406	20,174	7.1%

* Average Lead Times are 14.1 days at Warehouse A and 20.0 days at B
Average Total Daily Demand is 1010 units at Warehouse A and 400 units at B

of all, we see that if the present system could be and were rigorously enforced, the inventory investment could be reduced significantly - 37.2%. However, it is noted that this would result in an average runout of 12.6%. This runout is the best to be expected if the system is followed rigorously. Obviously the requirements for customer service are such that this high a runout situation could not be tolerated. The warehouse manager, operating semi-autonomously, has over compensated for the poor system design (30-75 days for all items independently of item value, and demand characteristics, and location) and is carrying too much inventory.

Use of the Least Total System Cost Analysis - System III shows that inventory investment can be reduced 32.4% and a resultant runout of 2.75%. The Total System Operating Costs are significantly improved from $8,153 down to $5,634 - a decrease of 30.9%. This cost reduction represents an operating profit which provides approximately a 100% return on the slightly larger inventory investment. At the same time, runout risk is reduced to one forth the former value. If these sample results were extended to the entire inventory, this represents over a three million dollar savings in average Inventory Investment over the System I (Actual) with equivalent system savings. Thus, it was apparent that System III represented a desirable system to consider; one that would produce satisfactory service and also provide an inventory investment savings.

There then remains the question. "Is this system - admittedly more intricate - substantially better than the classical inventory system in use for several decades [1] (depicted by System IV, Table II) ?" Also, comparing System III with System IV, one notes that while System III requires $3,549 more investment in inventory, there are total system savings of $729 per year (which amount is reduced by the fact that System IV is credited with return on investment in carrying cost component). This represents over a 20% return on the additional $3,549 investment which is obtained with one half the runout risk. It is also noted that System III is more consistent in runout at each of the two warehouses.

It was on this basis that System III seemed to offer the best results for the control of this company's inventory. These results are empirical and do not prove that System III would always be superior nor that it would be wise to implement in all similar situations. For example, if costs are not currently being developed and demand data is not available for preliminary analysis it would be advisable to install a simpler variable item system - say number IV as part of a long range program. In short the system should be of a design which will best fit a particular company's capabilities and needs.

Effect of Skewness of Demand Distribution

A simpler routine would be involved if the distribution of lead

time demand may be considered normal. However, it was soon found that this assumption would be a source of considerable error since there were many items with short lead times and others with highly skewed distributions of daily demand. Both of these factors had the effect of making the lead time demand skewed. System IIIa in Table II represents what would have happened in System III if the Skewness Factor were not applied in determining the appropriate V. D. for entering the tables. Here we observe that while Inventory Investment is reduced significantly, Total System Costs are increased moderately and average runout is increased rather drastically. Where pinpoint customer service in the way of stock availability is not required the assumption of normality offers a seemingly attractive approach. However, such practice is not recommended since it leads to spotty and unpredictable service and resultant lack of faith in the system.

CONCLUSION

The method presented offers opportunities for lower cost operation at satisfactory stock availability levels.

The methods used in the study also offer a means for evaluating the effect that suggestions made for improved operation would have in terms of Cost Reduction. Thus, a more generally acceptable answer to certain difficult policy and procedure questions is possible through such systems analysis. One example of such study was illustrated, namely that of evaluating the effect of lead time reduction upon inventory investment. The same approach can also be used in determining the value of reducing any of the specific costs that appear in the total cost equation.

As often happens in studies of this nature horizons are widened in the search for additional opportunities for cost reduction. A program for further system research can be developed which should lead to orderly and timely policies governing inventory. Perhaps the greatest benefit to management lies in this greater insight to the nature of problems with which it is faced.

TECHNICAL SUPPLEMENT

For the sake of exposition it has seemed best to defer some considerations to a section which need not be read by those interested primarily in the management and engineering aspects of the approach. Here, and a short discussion on cost determination is included, the more precise statement of the total cost equation is indicated but not developed, and the symbols and formula for the cost terms are stated.

Some notes on Determining Costs

Only variable costs are included in this inventory model. Costs which are unaffected by the Choice of X or Y are excluded.

Variable Costs of Resupply

Replacement stock orders result in costs at three locations:

(1) Branch warehouse ordering cost
(2) Central office review and processing costs
(3) Factory, or purchasing department order handling cost

Inventory Carrying Cost

This is the sum of five component costs that generally vary by item and by location:

(1) Interest on Invested Capital - This figure should be looked at from the point of view of what it actually costs to borrow money for inventory investment. Interest rates of 5-7% have been found to be representative. Items are valued at Standard Cost.
(2) Inventory Taxes - These may be personal property taxes or income taxes. These vary widely by state and should therefore be figured individually.
(3) Insurance - Insurance cost is proportional to actual inventory in place.
(4) Rent - This varies by location and by item. Actual space requirements per item should be determined.
(5) Obsolescence - This is directly proportional to size of inventory and is estimated from inventory control experience and life curves of various items.

Depletion Cost

Depletion cost was defined as the loss that occurs whenever customer demand cannot be supplied from the local warehouse. This cost may occur as a lost sale, the cost of referring the order to another warehouse, or the cost of deferring the order until resupply comes in. The evaluation of depletion cost requires measurement of each of the three possible costs plus a forecast of the relative proportion of the time each one will occur.

The cost of a lost sale is the profit that would have resulted from one additional sale. The normal profit of the item understates the profit that would accrue from making one more sale. The proper value to use in the marginal increment to profit. The marginal increment to profit is found by subtracting the increase in production cost from the increase in revenue which would have resulted from one additional sale.

The second type of depletion or runout cost is the cost of referring an order to another branch warehouse or to the factory. This cost is made up of telephone and/ or TWX communications to locate stock, additional clerical order preparation, and additional transportation expense.

The third type of runout cost is the cost of deferring a customer's order until normal resupply is received from the factory. Only clerical and communication expenses are involved in this cost.

The frequency of occurrence of the three costs at time of runout must be known to determine the composite cost of runout. Review of branch warehouse records and interviews with supervision yielded the proper proportions. In this way the existing practices and habits of the warehouse managers were built into the system. Further research is suggested to determine what effect these relative frequency levels have on total cost.

Good will is an important factor in depletion cost that has not been discussed in detail in this paper. It was determined that good will seemed to have little effect in the resulting inventory policy by the following reasoning:

The runouts predicted from the Total Cost Model were equivalent to best estimates of present experience - these runout percentages were acceptable to present customers. Further, customers were agreeable to a referral or deferral of their order in 80-90% of the instances when faced with an out-of-stock situation. Thus, rather large changes in C_R have only a small effect on the depletion cost term, which in turn has a small effect on the expected runout percentage. Since this runout percentage is the determinant of good will costs, it seemed logical to assume that good will did not need to be dealt with as an explicit cost, since the built in provisions of referral and deferral seemed to be operating satisfactorily.

COMPLETE TOTAL SYSTEM COST EQUATION AND SYMBOL LEGEND

The following represents a more precise expression for the Total Cost Equation. Upon partial differentiation and order-of-magnitude evaluation, this expression reduced to the equations in Y and Y^2 shown in the text.

$$C_T = \frac{C_O D}{Y+r\Sigma} + KD + \frac{C_I Y}{K'(Y+r\Sigma)} \left[X - \mu + \frac{1+r}{2}\Sigma + \frac{Y}{2} \right] + \frac{C_S D \Sigma}{Y+r\Sigma}$$

Where

C_T	=	Total System Variable Cost.
D	=	Mean Daily Demand for Item.
L	=	Lead Time in Days.
μ	=	DL, Demand During Lead Time L.
C_O	=	Cost of placing a replenishment Order.
C_I	=	Total Annual Variable Cost of Carrying Item in Inventory.
C_S	=	Cost Incurred whenever an Item Cannot be Supplied from Stock.
		$C_S = 1.5a C_L + b C_D + c C_R$
C_L	=	Cost of Lost Sale - Marginal Increment to Profit.
C_D	=	Cost of Deferring an Order.
C_R	=	Cost of Having Order Filled at Another Warehouse.
a, b, c	=	Percentages applicable to C_L, C_D and C_R.
r	=	$\frac{a+c}{a+b+c}$, Percent of Depletion Instances Where Local Warehouse Does Not Supply Customer.
Σ	=	$\sum_{i=1}^{\infty} iP_{X+i}$, Expected number of orders received in Excess of X during Lead Time L. Values from Normal Distribution.
σ_L	=	Standard Deviation of Lead Time Demand, $\sigma\sqrt{L}$
γ	=	Skewness Value, Used to Determine Skewness Factor in Correcting for Non-normal Lead Time Demands.
σ_L'	=	Standard Deviation of Lead Time Demand Corrected for Skewness $\sigma_L \cdot$ Skewness Factor.
X	=	Order Point.
Y	=	Order Quantity.
K'	=	Number of working days in the year.

TERMS USED IN DEVELOPING COSTS IN TABLE II

$E(C_T)$ = Expected Total Annual Variable Cost of Inventory System

$= E(C_O) + E(C_I) + E(C_S)$

$E(C_O)$ = Expected Annual Ordering Cost

$= \frac{264\, C_O \mu}{LY}$

$E(C_I)$ = Expected Annual Carrying Cost

$= C_I\left[X - \mu + \Sigma + \frac{Y}{2} \right]$

$E(C_S)$ = Expected Annual Depletion Cost

$= \frac{264\, C_S \mu}{LY}\, \Sigma$

Average Inventory in Units $= X - \mu + \Sigma + \frac{Y}{2}$

Runout Percentage for an item, $r = \frac{\Sigma}{Y+\Sigma}$

Where,

$\Sigma = \sum_{i=1}^{\infty} i P_{X+i}$ = Expected Percent Runout for a Cycle.

Average Runout Percent $= \frac{\sum C_S r}{\sum C_S}$

Where $\sum$ is now used in the usual sense of summation.

SKEWNESS FACTOR

The standard deviation of lead time demand should be increased to provide for skewness in the distribution of lead time demands. The skewness factor is determined from the exhibit following this page. This graph is entered through the horizontal scale by the skewness value calculated as follows:

$$\gamma = \frac{K_3^2}{LK_2^3}$$ where:

γ = the skewness value

K_3^2 = $[N\Sigma y^3 - 3N\Sigma y\Sigma y^2 + 2(\Sigma y)^3]^2$

K_2^3 = $[N\Sigma y^2 - (\Sigma y)^2]^3$

L = lead time

y = the daily demands for an item

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(1) Alford, L. P. and John R. Bangs, eds. Production Handbook, pp. 394 - 402, The Roland Press Company, New York, 1948.

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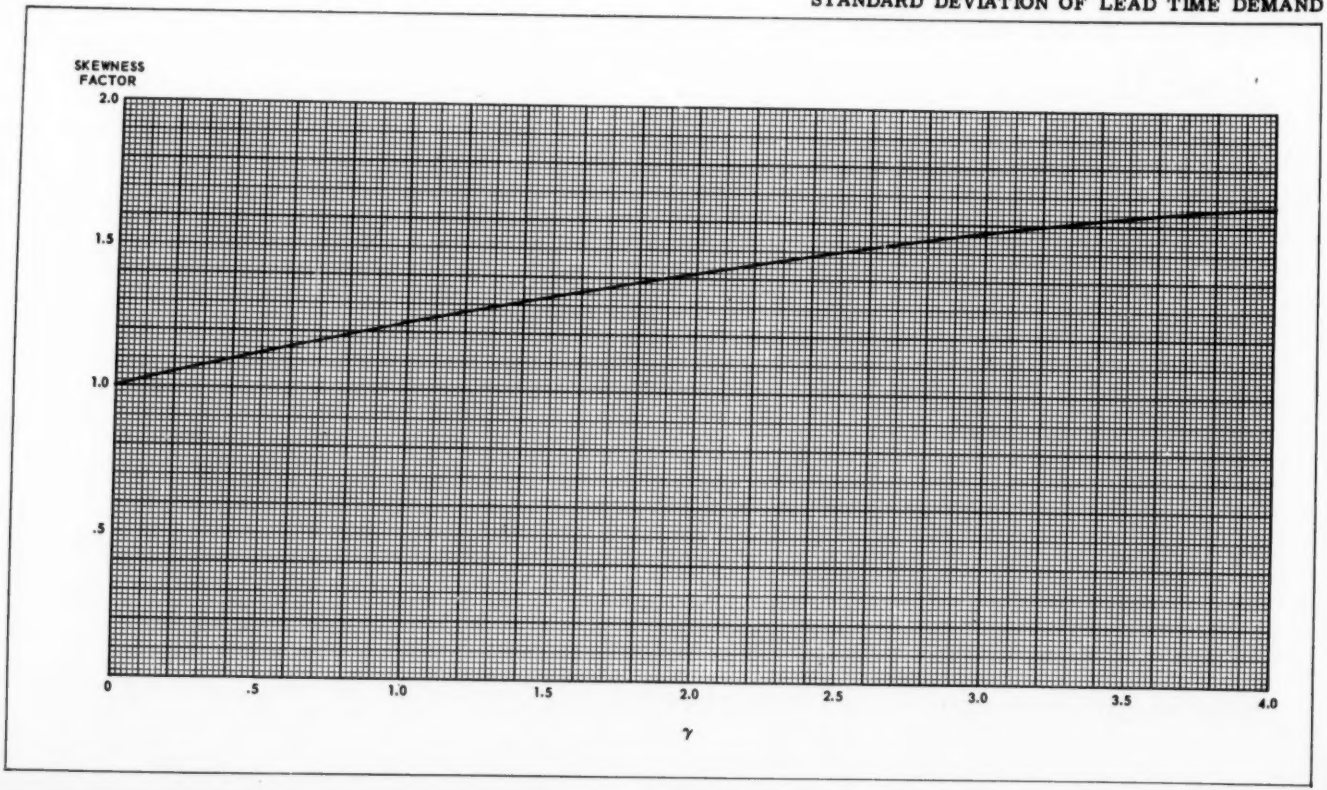
SKEWNESS FACTOR FOR INCREASING THE STANDARD DEVIATION OF LEAD TIME DEMAND



HUMAN RELATIONS RESEARCH AND INDUSTRIAL ORGANIZATIONS[1]

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During the past five years I have been interested in trying to acquaint myself with the empirical research pertinent for understanding human behavior in on-going organizations. As my reading progressed (in such fields as personality, clinical, social, and industrial psychology; industrial sociology; public administration; scientific management, etc.) I became increasingly aware that the integration of this seemingly diverse and scattered literature would help to provide some useful insights into the why of human behavior in on-going organizations thereby enlarging our scope of understanding. It seems unfortunate that relatively little attention is being paid to the process of integrating existing, discrete parts of research into more meaningful wholes. Too often the importance of integrating existing research is subserviated to so-called "individual research." But as Professor N. Bohr correctly points out the extension of knowledge can be increased by the recognition of relations between formerly unconnected groups of phenomena.[2]

A most difficult problem is to find an appropriate framework to integrate the many highly heterogeneous multi-level studies. The existing frameworks within any one academic discipline seem to be too narrow in scope to be useful. Those that cross the traditional discipline lines seem to be limited, primarily because they are too abstract and their concepts lack operational definitions by which to tie them to empirical reality.

The minimum requirements of a desired framework are that it show how one might cope with (1) organizational variables that exist on many different levels of analyses (2) whose existence depends upon their interrelatedness where each variable is (directly or indirectly) influencing, and is being influenced by, every other variable (3) resulting in a state of balance of the variables that has been variously called, the organization's "homeostasis," and "steady state."

After much experimentation and discussion a very simple framework was devised which seemed to be most suitable for integrating the literature keeping the above requirements in mind. The reasoning behind the choice of this framework may be outlined as follows:

1. It is agreed that organizational behavior is composed of many variables on different levels of analyses and with many interrelationships.

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[1]The results summarized in this paper are abstracted from a recent review of the literature made by the writer under a generous grant from the Foundation for Research on Human Behavior, Ann Arbor. Professor E. W. Bakke of the Labor & Management Center gave much constructive help throughout the project. Professor T. T. Holme, of the Department of Industrial Administration made available important typing assistance required by the writer. The report is to be published by Harper & Bros. in May 1957. It is tentatively entitled, The Behavioral Sciences & Organization: An Integrated Review of the Literature.

[2]Quoted in A. Tobalsky's review of International Encyclopedia of Unified Sciences, Vol. I, Part I. (ed.) O. Neuroth, R. Carnap & C. W. Morris, University of Chicago Press, 1955.

2. Even though organizational behavior looks like it is a "bloomin' buzzing confusion" some causal trends must be plotted if understanding is to be achieved. To plot these trends in terms of the traditional independent-dependent variable model would seem to do violence to the complexity of the phenomena under study.

3. The task might be accomplished by assuming that the complex organizational steady state that is the focus of the study evolved from very simple beginnings. Then one might attempt to reconstruct the (assumed) process by which this present complexity evolved. To put it in terms of a question, isn't it possible that the complex organizational steady state began as a result of a simple relationship between a few variables and then grew into the complexity with which the researcher is presently faced?

4. If it is assumed, for the moment, that the answer to the question above is in the affirmative, it follows that these initial few variables must be found, and the process by which their simple relationship evolved into the present complexity must be demonstrated. Moreover, if the framework is valid, the process which leads to the present organizational steady state must be evolved primarily from what is "inherent" in the relationship of the initial variables.

5. If such a framework is to have general applicability then it is further assumed that all of the organizations within the scope of inquiry have similar beginnings and go through a similar developmental process.

Having outlined some of the reasoning behind the framework chosen, a description of it is presented as follows:

1. The two basic variables to be dealt with are the individual and the formal organization.

2. It follows that in the relationship between these two initial variables lies the process by which the organizational complexity evolves.

3. The first step toward understanding the nature of this relationship is to ascertain the nature of each variable. Knowing the properties of these initial component variables, should make it possible therefore, to derive the nature of their relationship.

In the next section a discussion of some of the basic properties of personality will be followed by a similar discussion regarding formal organization from which an attempt will be made to derive some of the basic characteristics of the relationship that will tend to arise when these two initial components are "married" to form the beginnings of a social organization.[1]

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[1]This discussion is a very short summary of the detailed analysis to be found in the book cited in footnote one.

A. Some Properties of the Human Personality

The research on the human personality is so great and voluminous that it is indeed difficult to find agreement regarding its basic properties.[1] It is even more difficult to summarize the few agreements that may be inferred from the existing literature. Because of space limitations it is only possible to discuss in detail one (of ten agreements) which seems to the writer to be the most relevant to the problem at hand. The others may be summarized briefly as follows. Personality is conceptualized as (1) being an organization of parts where the parts maintain the whole and the whole maintains the parts; (2) seeking internal balance (usually called adjustment) and external balance (usually called adaptation); (3) being propelled by psychological (as well as physical) energy; (4) located in the need systems and (5) expressed through the abilities. (6) The personality organization may be called "the self" which (7) acts to color all the individual's experiences, thereby causing us to always live in our "private worlds" and which (8) is capable of defending (maintaining) itself against threats of all types.

The self, in this culture, tends to develop along specific developmental trends or dimensions which are operationally definable and empirically observable. The basic developmental trends may be described as follows. Human beings, in our culture:

1. Tend to develop from a state of being passive as an infant to a state of increasing activity as an adult. (This is what Erikson[2] has called self-initiative and Bronfenbrenner[3] has called self-determination.)

2. Tend to develop from a state of dependence upon others as an infant to a state of relative independence as an adult. Relative independence is the ability to "stand on one's own two feet" and simultaneously to acknowledge healthy dependencies.[4] It is characterized by the individual freeing himself from his childhood determiners of behavior (e.g., family) and developing his own set of behavioral determiners. This individual does not tend to react to others (e.g., the boss) in terms of patterns learned during childhood.[5]

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[1]The relevant literature in clinical, abnormal, child, and social psychology, personality theory, sociology and anthropology was investigated. The basic agreements inferred regarding the properties of personality are assumed to be valid for most contemporary points of view. Allport's "trait theory," Cattell's factor analytic approach and Kretschmer's somatotype framework are not included. For lay description see the author's Personality Fundamentals for Administrators, Yale Labor and Management Center, Rev. Ed., 1954.

[2]E. H. Erikson, CHILDHOOD AND SOCIETY (New York, 1950). See also R. Kotinsky, PERSONALITY IN THE MAKING (New York, 1952), pp. 8-25.

[3]Urie Bronfenbrenner, "Toward an Integrated Theory of Personality," PERCEPTION by Robert R. Blake and Glenn V. Ramsey (New York, 1951), pp. 206-257.

[4]This is similar to Erikson's sense of autonomy and Bronfenbrenner's state of creative interdependence.

[5]Robert W. White, LIVES IN PROGRESS (New York, 1952), pp. 339 ff.

3. Tend to develop from being capable of behaving only in a few ways as an infant to being capable of behaving in many different ways as an adult.[1]

4. Tend to develop from having erratic, casual, shallow, quickly dropped interests as an infant to a deepening of interests as an adult. The mature state is characterized by an endless series of challenges where the reward comes from doing something for its own sake. The tendency is to analyze and study phenomena in their full blown wholeness, complexity and depth.[2]

5. Tend to develop from having a short time perspective (i.e., the present largely determines behavior) as an infant to a much longer time perspective as an adult (i.e., where the behavior is more affected by the past and the future.)[3]

6. Tend to develop from being in a subordinate position in the family and society as an infant, to aspiring to occupy a more equal and/or superordinate position relative to their peers.

7. Tend to develop from a lack of awareness of the self as an infant to an awareness of and control over one's self as an adult. The adult who tends to experience adequate and successful control over his own behavior tends to develop a sense of integrity (Erikson) and feelings of a self-worth.[4]

These dimensions are postulated as being descriptive of a basic multi-dimensional developmental process along which the growth of individuals in our culture may be measured. Presumably ever individual, at any given moment in time could have his degree of development plotted along these dimensions. The exact location on each dimension will probably vary with each individual and even with the same individual at different times. Self-actualization may now be defined more precisely as the individual's plotted scores (or profile) along the above dimensions.[5]

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[1]Lewin and Kounin believe that as the individual develops needs and abilities, the boundaries between them become more rigid. This explains why an adult is better able than a child to be frustrated in one activity and behave constructively in another. See Kurt Lewin, A DYNAMIC THEORY OF PERSONALITY (New York, 1935), and Jacob S. Kounin, "Intellectual Development and Rigidity" in CHILD BEHAVIOR AND DEVELOPMENT, R. Barker, J. Kounin, H. R. Wright, editors (New York, 1943), pp. 179-198.

[2]Robert White, op. cit., pp. 347 ff.

[3]See the work by Bakke on workers' time perspective, E. W. Bakke, Citizens Without Work, Yale Univ. Press, 1940. Also Lewin reminds us of the billions of dollars that are invested in insurance policies. Kurt Lewin, "Times Perspective and Morale," RESOLVING SOCIAL CONFLICTS,(New York, 1948), p. 105.

[4]Carl R. Rogers, CLIENT-CENTERED THERAPY (New York, 1951.)

[5]Another related but discrete set of developmental dimensions may be constructed to measure the protective (defense) mechanisms individuals tend to create as they develop from infancy to adulthood. Exactly how these would be related to the above model is not clear.

A few words of explanation concerning these dimensions of personality development:

1. They are only one aspect of the total personality. All the properties of personality described to date must be used in trying to understand the behavior of a particular individual. For example, much depends upon the individual's self-concept, his degree of adaptation and adjustment, and the way he perceives his private world.

2. The dimensions are continual where the growth to be measured is assumed to be continuously changing in degree. An individual is presumed to develop continuously in degree, from the infant end to the adult end of each continua.

3. The only characteristic that is assumed to hold for all individuals is that, barring unhealthy personality development, they will be predisposed toward moving from the infant end to the adult end of each continuum. This is a model (a concept) describing the basic growth trends. As such, it does not make any predictions about any specific individual. It <u>does</u>, however, presume to supply the researcher with basic developmental continua along which the growth of any individual in our culture may be described and measured.

4. It is postulated that as long as one develops in a particular culture, one will never obtain maximum expression of these developmental trends. Clearly all individuals cannot be maximally independent, active, and so forth all the time and still maintain an organized society. It is the function of culture (e.g., norms, mores, and so forth) to exhibit <u>maximum</u> expression and to help an individual adjust and adapt by finding his <u>optimum</u> expression.

   A second factor that prevents maximum expression and fosters optimum expression is the individual's own finite limits set by his personality. For example, some people fear the same amount of independence and activity that others desire. Also it is commonplace to find some people who do not have the necessary abilities to perform specific tasks. No given individual is known to have developed all known abilities to their full maturity.

   Finally, defense mechanisms also are important factors operating to help an individual to deviate from the basic developmental trends.

5. The dimensions described above are constructed in terms of latent or genotypical characteristics. If one states that an individual needs to be dependent, this need will probably be ascertained by clinical inference because it is one that individuals are not usually aware of. Thus, if one observes an employee acting as if he were independent, it is possible that if one goes below the behavioral surface, the individual may be quite dependent. The obvious example is the employee who seems to behave always in a manner contrary to that desired by management. Although this behavior may look as if he is independent, his contrariness may be due to his great need to be dependent upon management, which he dislikes to admit to himself and to others.

One might say that an independent person is one whose behavior is not caused by the influence others have over him. Of course, no individual is completely independent. All of us have our healthy dependencies (i.e., those which help us to maintain our discreteness to be creative and to develop).

One operational criteria to ascertain whether an individual's desire to be, let us say, independent and active, is a true manifestation is to ascertain the extent to which he permits others to express the same needs. Thus an autocratic leader may say that he needs to be active and independent; he may also say that he wants subordinates who are the same; however, there is ample research to suggest that his leadership pattern only makes him and his subordinates more dependence-ridden.

B. Some Basic Properties of Formal Organization

The next step is to focus the analytic spotlight on the formal organization. What are its properties? What are its basic "givens?" What probable impact will they have upon the human personality? How will the human personality tend to react to this impact? What sorts of "chain reactions" are probable when these two basic components are brought together?

1. Formal Organizations Are Rational Organizations

Probably the most basic property of formal organization is its logical foundation or, as it has been called by students of administration, its essential rationality. It is the "mirror image" of the planners' conception of how the intended consequences of the organization may best be achieved. The underlying assumptions made by the creators of formal organization is that man within respectable tolerances will behave rationally, i.e., as the formal plan requires him to behave. Organizations are formed with a particular objective in mind and their structure mirrors these objectives. Although man may not follow the prescribed paths, and consequently the objectives might never be achieved, Simon suggests that by and large, man does follow these prescribed paths. As he points out, "Organizations are formed with the intention and design of accomplishing goals; and the people who work in organizations believe, at least part of the time, that they are striving toward these same goals. We must not lose sight of the fact that, however far organizations may depart from the traditional description...nevertheless most behavior in organizations is intendedly rational behavior. By "intended rationality" I mean the kind of adjustment of behavior to goals of which humans are capable--a very incomplete and imperfect adjustment, to be sure, but one which nevertheless does accomplish purposes and does carry out programs."[1]

Most of them emphasize that although no organization structure will exemplify the maximum expression of the principles, a satisfactory aspiration is for optimum expression, which means modifying the ideal structure to take into account the individual (and any environmental) conditions. Moreover, they urge that the people must be loyal to the formal structure if it is to never succeed without a "mental revolution." Fayol has the same problem in mind when he emphasizes the importance of esprit de corps.

[1]Herbert A. Simon, "Recent Advances in Organization Theory," RESEARCH FRONTIERS IN POLITICS AND GOVERNMENT (Washington, D. C., 1955), ch. ii, p. 30.

However, it is also true that these experts have provided little insight into why they believe that people should undergo a "mental revolution"; or why an esprit de corps is necessary if the principles are to succeed. The only hints usually found are that resistance to scientific management occurs because human beings "are what they are," or "because it's human nature." But, why does "human nature" resist formal organizational principles? Perhaps there is something inherent in the principles which causes human resistance. Unfortunately there exists too little research that specifically assesses the impact of the formal organizational principles upon human beings.

The formal organizational experts believe that logical, rational design, in the long run, is more human than creating an organization haphazardly. They argue that it is illogical, cruel, wasteful, and inefficient not to have a logical design. It is illogical because design must come first. It does not make sense to pay a large salary to an individual without clearly defining his position and its relationship to the whole. It is cruel because, in the long run, the participants suffer when no clear organizational structure exists. It is wasteful because, unless jobs are clearly pre-defined, it is impossible to plan logical training, promotion, resigning and retiring policies. It is inefficient because the organization becomes dependent upon personalities. The "personal Touch" leads to "playing politics" which Mary Follett has described as a "deplorable form of coercion."[1]

Unfortunately, the validity of these arguments tends to be obscured in the eyes of the behavioral scientist because it implies the only choice left, if the formal, rational, pre-designed structure is not accepted, is to have no organizational structure at all, with the organizational structure left to the whims, pushes and pulls of human beings. Some human relations researchers, on the other hand, have unfortunately given the impression that formal structures are "bad" and that the needs of the individual participants should be paramount in creating and administering an organization. However, a recent analysis of the existing research points up quite clearly that the importance of the organization as an organism worthy of self-actualization is being recognized by those who in the past have focussed largely upon the individual.[2]

In the past, and for the most part in the present, the traditional organizational experts based their "human architectual creation" upon certain basic principles, (more accurately) assumptions, about the nature of organization. These principles have been described by such people as Urwick,[3] Mooney,[4]

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[1]Ibid., pp. 36-39.

[2]Chris Argyris, THE PRESENT STATE OF RESEARCH IN HUMAN RELATIONS (New Haven, 1954), ch. 1.

[3]L. Urwick, THE ELEMENTS OF ADMINISTRATION (New York, 1944).

[4]J. D. Mooney, THE PRINCIPLES OF ORGANIZATION (New York, 1944).

Holden et al,[1] Fayol,[2] Dennison,[3] Brown,[4] Gulick,[5] White,[6] Gauss,[7] Stene,[8] Hopf,[9] and Taylor.[10]

Although these principles have been attacked by behavioral scientists, the assumption is made in this paper that to date no one has defined a more useful set of formal organization principles. Therefore, the principles are accepted as "givens". This frees us to inquire about their probable impact upon people, if they are used as defined.

In introducing these principles, it is important to note that, as Gillespie suggests, the roots of these principles may be traced back to certain "principles of industrial economics," the most important of which is the basic economic assumption held by builders of the industrial revolution that, "the concentration of effort on a limited field of endeavor increases quality and quantity of output."[11] It follows from the above that the necessity for specialization should increase as the quantity of similar things to be done increases.

1. Task (Work) Specialization

If concentrating effort on a limited field of endeavor increases the quality and quantity of output, it follows that organizational and administrative efficiency is increased by the specialization of tasks assigned to the participants of the organization.[12] Inherent in this assumption are three others. The first is that the human personality will behave more efficiently as the task that it is to perform becomes specialized. Second is the assumption that there can be found a one best way to define the job so that it is performed at greater speed.[13] Third is the assumption that any individual differences in the human personality may be ignored by transferring more skill and thought to machines.[14]

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[1]Paul E. Holden, Lounsbury S. Fish, and Hubert L. Smith, TOP MANAGEMENT ORGANIZATION AND CONTROL (New York, 1951).

[2]Henri Fayol, GENERAL AND INDUSTRIAL MANAGEMENT (New York, 1949).

[3]Henry S. Dennison, Organization Engineering (New York, 1931).

[4]Alvin Brown, ORGANIZATION OF INDUSTRY (New York, 1947).

[5]Luther Gulick, and L. Urwick, THE SCIENCE OF ADMINISTRATION (New York, 1937).

[6]L. D. White, INTRODUCTION TO THE STUDY OF PUBLIC ADMINISTRATION (New York, 1939).

[7]J. M. Gauss, L. D. White, and M. E. Demack, eds., THE FRONTIERS OF PUBLIC ADMINISTRATION (Chicago, 1936).

[8]E.D. Stene, "An Approach to a Science of Administration," AMER. POL. SCI. REV., Vol. 34 (Dec. 1940), pp. 1124-1137.

[9]Harry Arthur Hopf, MANAGEMENT OF THE OPTIUM, an address before the Sixth International Congress for Scientific Management, London, July 15-18, 1935; reprinted Hopf Institute of Management, Ossining, N. Y., 1935.

[10]F. W. Taylor, SCIENTIFIC MANAGEMENT (New York, 1948).

[11]James J. Gillespie, FREE EXPRESSION IN INDUSTRY (London, 1948), pp. 34-37.

[12]Herbert A. Simon, ADMINISTRATIVE BEHAVIOR (New York, 1947), pp. 80-81.

[13]For an interesting discussion see Georges Friedman, INDUSTRIAL SOCIETY (Glencoe, Ill., 1955), pp. 54 ff.

[14]Ibid., ch. iv., pp. 20. Friedman reports that 79% of Ford employees had jobs for which they could be trained in one week.

A number of difficulties arise with these assumptions when the properties of the human personality are recalled. First the human personality we have seen is always attempting to actualize its unique organization of parts resulting from a continuous, emotionally laden, ego-involving process of growth. It is difficult, if not impossible, to assume that this process can be choked off and the resultant unique differences of individuals ignored. This is tantamount to saying that self-actualization can be ignored. The second difficulty is that task specialization requires the individual to use only a few of his abilities. Moreover, as specialization increases, it tends to require the use of the less complex doing or motor abilities which, research suggests, tend to be of lesser psychological importance to the individual. Thus the principle violates two basic "givens" of the healthy adult human personality. It inhibits self-actualization and provides expression for few, shallow, skin-surface abilities that do not provide the "endless challenge" desired by the healthy personality.

2. Chain of Command

The principle of task specialization creates an aggregate of parts, each performing a highly specialized task. However, an aggregate of parts busily performing their particular objective does not form an organization. A pattern of parts must be formed so that the interrelationships among the parts create the organization. Following the logic of specialization, the planners create a new function (leadership) whose primary responsibility shall be the control, direction and coordination of the interrelationships of the parts, and to make certain that each part performs its objective adequately. Thus the assumption is made that administrative and organizational efficiency is increased by arranging the parts in a determinate hierarchy of authority where the part on top can direct and control the part on the bottom.

If the parts being considered are individuals, then they must be motivated to accept direction, control and coordination of their behavior. The leader, therefore, is assigned formal power to hire, discharge, reward and penalize the individuals in order that their behavior is molded toward the organization's objectives.

The impact of such a state of affairs is to make the individuals dependent upon, passive and subordinate to the leader. As a result, the individuals have little control over their working environment. At the same time, their time perspective is shortened because they do not control the information necessary to predict their future. These requirements of formal organization act to inhibit four of the growth trends of the personality because to be passive, subordinate, and to have little control and short time perspective exemplify dimensions, in adults, of immaturity, not adulthood.

The planners of formal organization suggest three basic ways to minimize this admittedly difficult position. First, ample rewards should be given to those who perform well and who do not permit their dependence, subordination, passivity, etc. to influence them in a negative manner. The rewards should be material and psychological. Because of the specialized nature of the job, however, few psychological rewards are possible. It becomes important, therefore, that adequate material rewards are made available to the productive employee. This practice can lead to new difficulties, since the solution is, by its nature, not to do anything about the on-the-job situation (which is what is causing the difficulties) but to pay the individual for the dissatisfactions he experiences. The end result is that the employee is paid for his dissatisfaction while at work and his wages are given to him to gain satis-

factions outside his immediate work environment.

Thus the management helps to create a psychological set which leads the employees to feel that basic causes of dissatisfaction are built into industrial life; that the rewards they receive are wages for dissatisfaction and that if satisfaction is to be gained, the employee must seek it outside the organization.

To make matters more difficult, there are three assumptions inherent in the above solution that also violate the basic "given" of human personality. First, the solution assumes that a whole human being can split his personality so that he will feel satisfied in knowing that the wages for his dissatisfaction will buy him satisfaction outside the plant. Second, it assumes the employee is primarily interested in maximizing his economic gains. Third, it assumes that the employee is best rewarded as an individual producer. The work group in which he belongs is not viewed as a relevant factor. If he produces well, he should be rewarded. If he does not, he should be penalized even though he may be restricting production because of informal group sanctions.

The second solution suggested by the planners of formal organization is to have technically competent, objective, rational, loyal leaders. The assumption is made that if the leaders are technically competent, presumably they cannot have "the wool pulled over their eyes;" which should lead the employees to have a high respect for them. The leaders should be objective and rational and personify the rationality inherent in the formal structure. Being rational means that they must avoid becoming emotionally involved. As one executive states, "We try to keep our personality out of the job." The leader must also be impartial. He does not permit his feelings to operate when he is evaluating others. Finally, the leader must be loyal to the organization so that he can inculcate the loyalty in the employees that Taylor, Fayol and others believe is so important.

Admirable as this solution may be, again it violates several of the properties of personality. If the employees are to respect an individual for what he does rather than for who he is, the sense of self integrity based upon evaluation of the total self which is developed in people, is lost. Moreover, to ask the leader to keep his personality out of his job is to ask hom to stop actualizing himself. This is not possible as long as he is alive. Of course, the executive may want to feel that he is not involved, but it is a basic "given" that the human personality is an organism always actualizing itself. The same problem arises with impartiality. No-one can be completely impartial. As has been shown, the self concept always operates when we are making judgments. In fact, as Rollo May has pointed out, the best way to be impartial is to be as partial as one's needs predispose him to be but be aware of this partiality in order to "correct" for it at the moment of decision.[1] Finally, if a leader can be loyal to an organization under these conditions, there may be adequate grounds for questioning the health of his personality make-up.

The third solution suggested by many adherents to the formal organizational principles is to motivate the subordinates to have more initiative and to be more creative by placing them in competition with one another for

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[1] Rollo May, "Historical and Philosophical Presuppositions for Understanding Therapy," in O. H. Mowrer, PSYCHOTHERAPY THEORY AND RESEARCH (New York, 1953), pp. 38-39.

the positions of power that lie above them in the organizational ladder. This solution is traditionally called "the rabble hypothesis." Acting under the assumption that employees will be motivated to advance upwards, the formal organizational adherents add another assumption that competition for the increasingly (as one goes up the ladder) scarcer positions will increase the effectiveness of the participants. Williams,[1] conducting some controlled experiments, shows that the latter assumption is not necessarily valid with people placed in competitive situations. Deutsch,[2] as a result of extensive controlled experimental research supports Williams' results and goes much further to suggest that competitive situations tend to lead to an increase in tension and conflict and a decrease in human effectiveness. Levy and Freedman confirm Deutsch's findings and go further to relate competition to psychoneurosis.[3]

3. Unity of Direction[4]

If the tasks of everyone in a unit are specialized, then it follows that the objective or purpose of the unit must be specialized. The principle of unity of direction states that administrative and organizational efficiency increases if each unit has a single (or homogeneous set of) activity (activities) that are planned and directed by the leader.

This means that the work goal toward which the employees are working, the path towards the goal, and the strength of the barriers they must overcome to achieve the goal are defined and controlled by the leader. Assuming that the work goals do not ego-involve the employees, (i.e., they are related to peripheral skin-surface needs), then ideal conditions for psychological failure have been created. The reader may recall that a basic "given" of a healthy personality is the aspiration for psychological success. Psychological success is achieved when each individual is able to define his own goals, in relation to his inner needs and the strength of the barriers to be overcome in order to reach these goals. Repetitive as it may sound, it is nevertheless true that the principle of unity of direction also violates a basic "given" of personality.

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[1] L. C. S. Williams, "Effects of Competition Between Groups in a Training Situation," OCCUP. PSYCHOL., Vol. 30, No. 2 (April 1956), pp. 85-93.

[2] M. Deutsch, "The Effects of Cooperation and Competition Upon Group Process," Human Relations, Vol. 2 (1949), pp. 129-152.

[3] Stanley Levy and Lawrence Freedman, "Psychoneurosis and Economic Life," Social Problems, Vol. 4, No. 1, July 1956, pp. 55-67.

[4] The sacredness of these principles is questioned by a recent study. Heckscher concludes that the principles of unity of command and unity of direction are formally violated in Sweden. "A fundamental principle of public administration in Sweden is the duty of all public agencies to cooperate directly without necessarily passing through a common superior. This principle is even embodied in the constitution itself, and in actual fact it is being employed daily. It is traditionally one of the most important characteristics of Swedish administration that especially central agencies, but also central and local agencies of different levels, cooperate freely and that this is being regarded as a perfectly normal procedure." Gunnar Heckscher, SWEDISH PUBLIC ADMINISTRATION AT WORK SNS (Stockholm, Sweden, 1955), p. 12.

4. Span of Control[1]

The principle of span of control states that administrative efficiency is increased by limiting the span of control of a leader to no more than five or six subordinates whose work interlocks.[2]

It is interesting to note that Dale,[3] in an extensive study of the organizational principles and practices in 100 large organizations, concludes that the actual limits of the executive span of control are more often violated than not. Worthy[4] reports that it is formal policy in his organization to extend the span of control of the top management much further than is theoretically suggested. Finally Suojanen,[5] in a review of the current literature on the concept of span of control, concludes that it is no longer valid; particularly as applied to the larger government agencies and business corporations. Healey's findings contradict Suojanen's. He reports that the concept of span of control presently used closely adheres to that advocated in theory.[6]

In a recent article, however, Urwick[7] criticizes the critics of the span of control principle. For example, he notes that in the case of Worthy, the superior has a large span of control over subordinates whose jobs do not interlock. The buyers in Worthy's organization purchase a clearly defined range of articles; therefore, find no reason to interlock with others.

Simon criticizes the span of control principle on the grounds that it increases the "administrative distance" between individuals. An increase in administrative distance violates, in turn, another formal organizational principle that administrative efficiency is enhanced by keeping at a minimum the number of organizational levels through which a matter must pass before it is acted on."[8] Span of control, continues Simon, inevitably increases red tape since each contact between agents must be carried upward until a common superior is found. Needless waste of time and energy result. Also, since the solution of the problem depends upon the superior, the subordinate is in a position of having less control over his own work situation. This places the subordinate in a work situation which is less mature.

Although the distance between individuals in different units increases (because they have to find a common superior) the administrative distance between superior and subordinate within a given unit decreases. As Whyte[9]

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[1] First defined by V.A. Graicunas in an article entitled "Relationship in Organization," in Papers on the Science of Administration, L. Gulick and L. Urwick, eds., pp. 183-187.

[2] L. Urwick, SCIENTIFIC PRINCIPLES AND ORGANIZATION (New York, 1938), p. 8.

[3] Ernest Dale, PLANNING AND DEVELOPING THE COMPANY ORGANIZATION STRUCTURE (New York, 1952), ch. xx.

[4] James C. Worthy, "Organizational Structure and Employee Morale," American Soc. Rev. (April 1950), pp. 169-179.

[5] W.W. Suojanen, "The State of Control Fact of Trouble," ADV. MGT. (Nov. 1955), Vol. 20, ch. xi., pp. 5-13.

[6] James H. Healey, "Coordination and Control of Executive Functions," Personnel, Vol. 33, No. 2, Sept. 1956, pp. 106-117.

[7] L. Urwick, "The Manager's Span of Control," HARV. BUS. REV. (May-June, 1946).

[8] Herbert A. Simon, ADMINISTRATIVE BEHAVIOR (New York, 1947), pp. 26-28.

[9] William Whyte, ON THE EVOLUTION OF INDUSTRIAL SOCIOLOGY: Mimeographed copy of paper to be presented at the 1956 meeting of the American Sociological Society.

correctly points out, the principle of span of control, by keeping the number of subordinates at a minimum, places great emphasis on close supervision. Close supervision leads the subordinates to become dependent upon, passive towards, and subordinate to the leader. Thus we must conclude that span of control, if used correctly, will tend to increase the subordinate's feelings of dependence, submissiveness, passivity, etc. In short, it will tend to create a work situation which requires immature, rather than mature, participants.

C. A Basic Incongruency Between the Needs of a Mature Personality and Requirements of Formal Organization

Bringing together the evidence regarding the impact of the formal organizational principles upon the individual, it is concluded that there are some basic incongruencies between the growth trends of a healthy personality and the requirements of the formal organization. If the principles of formal organization are used as ideally defined, then the employees will tend to work in an environment where (1) they are provided minimal control over their work-a-day world, (2) they are expected to be passive, dependent, subordinate, (3) they are expected to have a short time perspective, (4) they are induced to perfect and value the frequent use of a few skin-surface, shallow abilities and (5) they are expected to produce under conditions leading to psychological failure.

All of these characteristics are incongruent to the ones healthy human beings are postulated to desire. They are much more congruent with the needs of infants in our culture. In effect, therefore, formal organizations are willing to pay high wages and provide adequate seniority if mature adults will, for eight hours a day, behave in a less mature manner! If the analysis is correct, this inevitable incongruency increases as (1) the employees are of increasing maturity; (2) as the formal structure (based upon the above principles) is made more clear cut and logically tight for maximum formal organizational effectiveness, (3) as one goes down the line of command and (4) as the jobs become more and more mechanized, (i.e., take on assembly line characteristics).

As in the case of the personality developmental trends, this picture of formal organization is also a model. Clearly, no company actually uses the formal principles of organization exactly as stated by their creators. There is ample evidence to suggest that they are being modified constantly in actual situations. However, those who expound these principles would probably be willing to defend their position that this is the reason why human relations problems exist; the principles are not followed as they should be.

In the model of the personality and the formal organization, we are assuming the extreme of each in order that the analysis and its results can be highlighted. Speaking in terms of extremes helps us to make the position sharper. In doing this, no assumption is made that all situations in real life are extreme (i.e., that the individuals will always want to be more mature and that the formal organization will always tend to make people more dependent, passive, and so forth, all the time.) The model ought to be useful, however, to plot the degree to which each component tends toward extremes and then to predict the problems that will tend to arise.

Stating the basic findings up to this point in terms of propositions one could state:

Proposition I. There is a Lack of Congruency Between the Needs of Healthy Individuals and the Demands of the Formal Organization.

If one uses the traditional formal principles of organization (i.e., traditional chain of command, task specialization, etc.) to create a social organization, and

if one uses as an input, agents who tend toward a mature state of psychological development (i.e., they are predisposed toward relative independence, activeness, use of important abilities, etc.),

then one creates a disturbance, because the needs of healthy individuals listed above are not congruent with the requirements of formal organization, which tends to require the agents to work in situations where they are dependent, passive, use few and unimportant abilities, etc.

Corollary.[1] The disturbance will vary in proportion to the degree of incongruency between the needs of the individuals and the requirements of the formal organization.

An administrator is, therefore, always faced with an inherent tendency toward continual disturbance.

Drawing on the existing knowledge of the human personality, a second proposition can be stated.

Proposition II. The Resultants of this Disturbance are Frustration, Failure, Short Time Perspective and Conflict.

If the agents are predisposed to a healthy, more mature self-actualization:

1. They will tend to experience frustration because their self-actualization will be blocked.[2,3]

2. They will tend to experience failure because they will not be permitted to define their own goals in relation to central needs, the paths to these goals, etc.[4,5]

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[1]In the full analysis, specific conditions are derived under which the basic incongruency increases or decreases.

[2]Roger B. Barker, T. Dembo and K. Lewin, FRUSTRATION AND REGRESSION (Univ. of Iowa, 1941).

[3]John Dollard et al, FRUSTRATION AND AGRESSION (New Haven, Conn., 1939).

[4]Kurt Lewin et al, "Level of Aspiration," PERSONALITY AND THE BEHAVIOR DISORDERS, J. McV. Hunt, ed., (New York, 1944), ch. xx, pp. 333-378.

[5]Ronald Lippitt and Leland Bradford, "Employee Success in Work Groups," PERSONNEL ADMINISTRATION, Vol. 8 (Dec. 1945), ch. lv, pp. 6-10.

3. They will tend to experience short time perspective because they have no control over the clarity and stability of their future.[1]

4. They will tend to experience conflict because, as healthy agents, they will dislike frustration, failure and short time perspective which is characteristic of the present job. However, if they leave they may not find a new job easily, and/or even if a new job is found, it may not be much different.[2]

Based upon the analysis of the nature of formal organization, one may state a third proposition.

Propostion III. Under Certain Conditions the Degree of Frustration, Failure, Short Time Perspective and Conflict will Tend To Increase.

The resultants of the disturbance in the organization will tend to increase in degree:

1. As the individual agents increase in degree of maturity (as operationally defined in the personality model), and/or

2. As the degree of dependence, subordination, passivity, etc., increase, these tend to increase:

   a. As one goes down the chain of command.
   b. As directive leadership increases.
   c. As management controls are increased.
   d. As human relations programs are undertaken but improperly implemented and/or

3. As the jobs become more specialized, and/or

4. As the exactness with which the traditional formal principles are used increases.

Proposition IV. The Nature of the Formal Principles of Organization Cause the Subordinate, At Any Given Level, to Experience Competition, Rivalry, Inter-Subordinate Hostility and to Develop a Focus Toward the Parts Rather Than the Whole.

1. Because of the degree of dependence, subordination, etc. of the subordinates upon the leader, and because the number of positions above any given level always tend to decrease, the subordinates aspiring to perform effectively[3] and to advance will tend to find themselves in competition with, and receiving hostility from each other.

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[1]Kurt Lewin, "Time Perspective and Morale," RESOLVING SOCIAL CONFLICTS (New York, 1948), Gertrud Weiss Lewin, ed., pp. 103-124.

[2]Theodore M. Newcomb, SOCIAL PSYCHOLOGY (New York, 1950), pp. 361-373.

[3]These problems may not arise for the subordinate who decides to become apathetic, disinterested, etc.

2. Because according to the formal principles, the subordinates are directed towards and rewarded for, performing their own task well, the subordinates tend to develop an orientation toward their own particular part rather than towards the whole.

3. This part-orientation increases the need for the leader to coordinate the activity among the parts in order to maintain the whole. This need for the leader, in turn, increases the subordinates degree of dependence, subordination, etc. This creates a circular process whose impact is to maintain and/or increase the degree of dependence, subordination, etc., plus the rivalry and competition for the leader's favor.

Up to this point a few of the resultants of the relationship between the initial components of organization; the human personality and the formal organization have been analyzed in some detail. Clearly I have not begun to describe the complexity one usually finds when observing social organizations. Although time and space do not permit a continuation of this analysis to demonstrate how much more of the commonly observed organizational behavior can be derived in detail as a natural extension of the framework stated up to this point, it might be useful at least, to indicate some of the results.

Continuing from Proposition II, it can be shown that under conflict, frustration, failure, and short time perspective, the employees will tend to maintain self integration by creating specific adaptive (informal) behavior such as:[1]

1. Leaving the organization.
2. Climbing the organizational ladder.
3. Manifesting defense reactions such as (day dreaming, aggression, ambivalence, regression, projection, etc.).
4. Becoming apathetic and disinterested toward the organization, its make-up and goals. This leads to such phenomena as:

   a. employees reduce the number and potency of the needs they expect to fulfill while at work.
   b. employees goldbrick set rates, restrict quotas, make errors, cheat, slow down, etc.

5. Creating informal groups to sanction the defense reactions and the apathy, disinterested and lack of self involvement.
6. Formalizing the informal groups.
7. Evolving group norms that perpetuate the behavior outlined in 3, 4, 5 and 6 above.
8. Evolving a psychological set that human or non material factors are becoming increasingly unimportant, while material factors become increasingly important.
9. Acculturating the youth to accept the norms discussed in 7 and 8.

[1]Adaptive activities numbered one to nine became major categories under which much empirical research can be included.

Comparing the informal behavior with that prescribed by the formal organization, we may state:

Proposition V. The Employee Adaptive Behavior Maintains Individual Self Integration and Simultaneously Impedes Adaptation With the Formal Organization.

Proposition VI. The Adaptive Behavior of the Employees Has a Cumulative Effect, Feedbacks Into the Organization, and Reinforces Itself.

1. All these adaptive reactions reinforce each other so that they not only have their individual impact on the system, but they also have a cumulative impact. Their total impact is to increase the degree of dependence, submissiveness, etc., and increase the resulting turnover, apathy, disinterest, etc. Thus a feedback process exists where the adaptive mechanisms become self-maintaining.

2. The continual existance of these adaptive mechanisms tend to make them norms or codes which, in turn, act to maintain the adaptive behavior and to make it the proper behavior for the system.

3. If 2 is valid, then employees who may desire to behave differently will tend to feel deviant, different, not part of the work community (e.g., rate busters).

The individual and cumulative impact of the defense mechanisms is to influence the output-input ratio in such a way that a greater input (energy, money, machines) will be required to maintain a constant output.

Proposition VII. Certain Management Reactions Tend to Increase the Antagonisms Underlying the Adaptive Behavior.

1. Those managements that base their judgment on the logics of the formal organization and their self-concept, will tend to dislike the employee adaptive behavior. They also will tend to diagnose the problem behavior of the employee to be the fault of the employee. It follows, therefore, for these managements that they should tend to take those "corrective" actions that are congruent with their self-concept and the logics of formal organization. These actions tend to be:

   a. Increasing the degree of directive leadership.
   b. Increasing the degree of management controls.
   c. Increasing the number of pseudo-human relations programs.

The first two modes of reaction tend to compound, reinforce and help to maintain the basic disturbance outlined in Proposition I. It follows, therefore, that the behavior included in Propositions IV, V, and VI will also be reinforced. (This is the behavior management desires to change in the first place). The third mode of reaction tends to increase the distance and mistrust between employee and management because it doesn't jibe with the realities of the system within which the employee works.

The present employees influence the attitudes of future employees. They will tend to behave according to their self-concept, thus acculturating the future employees (future input) to the nature of the internal system and the adaptive behavior.

One must conclude that the management behavior described in Proposition 7 primarily acts to influence the output-input ratio so that a much greater input is required to obtain the same constant output, or that a disproportionately higher input will be necessary for a given increment of increased output.

Is there a way out of this circular process? The basic problem is to decrease the degree of dependency, subordination, submissiveness, etc. It can be shown that job enlargement, employee-centered (or democratic or participative) leadership are a few factors which, if used correctly, can go a long way toward ameliorating the situation. However, these are limited because their success depends upon having employees who are ego-involved: highly interested in the organization. The adaptive behavior listed above, predisposes the employee to disinterest, non-ego-involvement and apathy. The existence of such states of affairs, in turn, acts to require the more directive leadership pattern to "motivate" and control the disinterested employee. The directive leadership pattern, in turn, requires strong management controls if it is to succeed. But, as we have seen, directive leadership and management controls actually create the human problems that one is trying to solve. This dilemma between the needs of the individuals and the demands of the organization is a basic, continual dilemma posing an eternal challenge to the leader. How is it possible to create an organization in which it is possible for the individuals to obtain optimum expression and, simultaneously for the organization to obtain optimum satisfaction of its demands?

Although a few suggestions may be found in the literature, they are, by and large, untested and wanting systematic rigour. Here lies a fertile field for future research in organizational behavior.

HOW TO MAKE A COMPUTER FEASIBILITY STUDY

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In the modern world of high-powered publicity, advertising and public relations, the past five years have seen many crusades, crises and miracles come and go. One of the most consistently popular themes has had to do with the wonders of science and how scientific achievements are increasingly affecting us all. Depending apparently upon the personal sensibilities of the forecaster, the prediction is either for glorious happiness or impending doom. One aspect of the general theme has involved electronic data processing, and the breadth and intensity of concern with matters covered by this term must indeed by considered a tribute to the effectiveness of the modern huckster, whether or not you happen to agree with his means or his ends.

These remarks are not intended to imply that there is a void behind the facade of electronic data processing. Rather, they are meant, by contrast, to emphasize the need for a sober approach to an easily-popularized subject. The introduction and use of electronic data processing equipment should be considered as one of many means by which an organization can more effectively direct and use the human ingenuity available to it. This overriding concept - implying both the popular promises of cost reduction and improved management control, but tied to neither - has gradually gained recognition, and concurrently a pattern for orderly evaluation of the problems and potentialities of electronic data processing equipment has evolved. This pattern has become known as a Feasibility Study.

It has been aptly said that a feasibility study is "decision in the making." In practical terms, a feasibility study can be two things to any company that undertakes it. First, it can be a relatively inexpensive way to find out whether competitors are gaining ground. Secondly, and preferably, it can be a process of fact-finding and ordinary business planning that is amply justified by the scale, the term and the relatively irrevocable nature of commitments that will be made if electronic data processing equipment is acquired.

Because of the similarity between a feasibility study and normal, sound business planning, the study technique in relation to electronic data processing has definable phases which are not unlike those involved in entering a new field of business.

> The first phase is that in which the need for concentrated study is agreed upon and the planning of the study itself takes place.
>
> The second phase involves the collection, reduction and assimilation of background information by those who are conducting the study.
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> At the third stage, the concentrated analysis of fields of application for electronic data processing equipment, and the synthesis of these studies into data processing system plans, takes place.
>
> The fourth phase provides electronic equipment manufacturers an opportunity to specify what their products will do in particular applications.
>
> Finally, the fifth phase is that of evaluation and decision, based

upon the study.

Each of the foregoing steps deserves further comment, since my own and others' experiences indicate there are both pitfalls and opportunities along the way.

Setting Up A Feasibility Study Program

First, with regard to getting underway, considerably more is needed than the simple charge to someone to "look into electronics". Specific provision should be made at the outset for review of progress of the study work at set intervals. Review of progress, in turn, implies that objectives of the study have been set and the authority and responsibility of individuals involved in the study has been established, even though these may be revised as the work progresses. Unless the study is to be extremely narrow in terms of the potential application fields involved (which should not be the case), the study program should have broad sponsorship among top functional managers of the business. This sort of broad backing can sometimes be attained and held by drawing the people who are to conduct the study from several departments or divisions of the company. A little concern with considerations of this type at the beginning can mean a lot later on in terms of the ease of conduct of the study and ready acceptance of conclusions supported by it.

It is also worthwhile to assure in the beginning that high level managers understand what the alternatives to a thorough feasibility study are. There are not many, and consideration of them, as part of the fundamental decision regarding the extent and nature of the feasibility study, can only serve to develop a clearer definition of objectives in the beginning. On the one hand, a company may choose to ignore the electronics fanfare, stick with its present ways and play the role of bystander. We should not be too critical of such a decision, incidently, because it may be eminently sound in the complex context of a particular company's other commitments, present state of organizational development, sales outlook, etc. Nevertheless, this choice cannot be expected to stand indefinitely, and it should be recognized for what it is; a choice of timing alone.

The opposing alternative, standing on the opposite side of a decision to undertake a feasibility study, is a choice of immediate commitment to install some type of electronic data processing equipment. The companies in which such a decision is defensible are very few, because it is only really justifiable in cases where some group within the organization, without being specifically charged to do so, has already covered the ground that would be explored during a feasibility study and has developed reasonable plans for the introduction of electronic data processing equipment. It is possible that this has been the case in some companies with long-standing, well-developed systems and procedures or industrial engineering departments. Trying to get a conversion program underway without a feasibility study, however, will almost certainly reveal that such an approach in no way removes the necessity for undertaking equivalent study and planning work.

Parenthetically, however, let me give credit where it is due. What can be seen so clearly today as representing a reasonable, orderly approach to planning and effecting data processing equipment installation is visible largely through the experience of those individuals and organizations which, in the past, were blessed with both the vision to see the potential rewards from the use of such equipment and the fortitude to risk heavy commitments

on the unknown. That there is today a body of knowledge, experience and principles in this field to study and plan with before making a major decision, is due almost solely to the efforts of these pioneers. The rewards they are gaining are certainly justified.

Equipment and Application Background

If we assume that the foregoing considerations have been adequately weighed and have resulted in authorization for a thorough feasibility study, the initial survey of available background information is the next step. For those who are directly involved in the study work, this will probably be the most interesting phase of their activity. They will learn a tremendous amount in a short time about computers and their associated peripheral equipment, about the often-compensating yardstick characteristics of size, speed, capacity, flexibility and accuracy that apply to particular systems and about the problems and complexities of computer programming and operation. They will also begin to build the basis for judgment of application possibilities, which gets to the heart of feasibility study work.

The sources of this important background information are very broad, and all of them should be explored. The two most important and fruitful contacts to be made are with the manufacturers and the users of existing electronic data processing equipment. At a minimum, the introductory computer courses of several manufacturers should be attended. Furthermore, the study group people should each attend more than one of these; that is, one person attending one manufacturer's courses while another learns about a different manufacturer's equipment is not likely to provide the necessary individual understanding of principles and contrasting techniques that will be required in later stages of the feasibility study, when comparative judgments on equipment, in terms of the specific company's applications must be made.

It is important, too, that members of a feasibility study group contact people in the manufacturers' organizations other than sales and training personnel. To arrive at sound conclusions during and from the feasibility study, the participants in the study must gain an understanding and appreciation of the future as the manufacturer sees it, so that short term plans can be properly oriented to probable future developments. Because the electronics field generally has a more rapid technological development rate than the great majority of industries today, it is important that the plans laid on the basis of the feasibility study be consistent with the progress that will be coming, rather than being a strait-jacket making later major readjustments inevitable.

One of the best ways to get background of this nature is to talk with the manufacturers' research people, their product planning personnel, information science staffs, and other similar groups. Within the manufacturers' organizations, it is these people who are trying to shape the hardware of 5 or 10 years hence. They are constantly engaged in weighing opposing considerations such as hardware cost versus programming difficulty, automatic programming development versus optimum equipment utilization, and a host of other dichotomies, in an attempt to develop the characteristics of improved data handling equipment. There should not be too much difficulty in getting behind the salesman to these people, since it is important to them, also, to be in frequent contact with informed members of feasibility study groups, as well as experienced users. They are constantly in need of better information on the nature of the users' problems, his potential applications and his probable practical rate of application progress.

Opportunity to discuss problems, plans and progress with representatives of organizations who are already involved in electronic equipment applications can be had through equipment manufacturers and through attendance at the many meetings being held around the country today that deal with various aspects of the data processing field. The professional society meetings are increasingly important marshalling points for the people and the problems of data processing with which members of a feasibility study group should be well acquainted. Membership in such societies as well as awareness of work being done by their members can be crucial to the attainment of the thorough background that should be obtained by people conducting a feasibility study. The contacts made at such meetings can also be a means for selective visits to users' installations for more detailed discussions. It has been my experience that there is a spirit of camaraderie among people whose responsibilities relate to electronic data processing that is definitely to the advantage of the newcomer.

Beyond these principal means for obtaining abundant background on the technicalities and experience in the electronic data processing field, there are a host of publications, from books to pamphlets, that can be referred to, and survey services, in up-dated, reference book form, are also available. User groups, holding regular meetings and having a common bond of location, equipment used or problems faced, have been formed and may be contacted. From the experience of participation, I can give testimony to the advantage of such meetings as forums for exchange of ideas and techniques. In summary, there are few problems, beyond those of simple learning, connected with this part of a feasibility study.

Application Analysis

When a fair amount of equipment and user-experience background has been obtained by the study group, additional background collection and assimilation can become a less concentrated activity and the third phase of the feasibility study - application analysis within the group's own organization - can begin. Thereafter, the distinction between the two phases will be difficult to make at times, because the work and interim results of one will strongly influence the other. This is as it should be, since the conclusions of the feasibility study depend to a large degree on a synthesis of knowledge gained from both phases.

Application studies may be difficult or easy, depending upon many factors peculiar to the particular organization within which the feasibility study is being carried on. The prior experience of the people conducting the study, their sponsorship in the organization, the awareness of line managers and supervisors of the purpose and potential effect of the study itself, the extent and nature of previous experience in the company with data handling equipment - these and many other factors will influence the course of the study. "Made-to-order" applications may be easy to find, or considerable time may be spent simply in selection of an application-field worthy of detailed study. Nevertheless, detailed analysis of several potential areas must take place.

The conduct of such studies will involve the usual techniques of the industrial engineer, the systems man, and the management scientist. Detail studies of present procedures must be made, then flow-charted and analyzed. This work must then be checked and discussed with the line management personnel holding responsibility for the functions to which the data processing is related, in order to check facts, determine real objectives of each function and reveal complexities and problems not readily apparent. Finally,

synthesis of these studies must be undertaken to develop in considerable detail a procedural description of a new system, utilizing electronic data processing equipment.

These processes are not new, and their use in an electronic data processing equipment feasibility study would seem to need no more than mention to be clear. However, there are a few points to be made regarding techniques and viewpoints that have important applicability in this context.

First, it should become obvious to members of a feasibility study group before they have gone very far that existing data handling methods and procedures within an organization are seldom logically planned and controlled processes. The most notable characteristic revealed by close study is that procedures applicable to a particular functional responsibility segment have been severely affected by the ebb and flow of external conditions which govern the size and nature of the given responsibility segment. Procedures grow, adjust and disappear primarily as a function of the pattern of organization and the physical environment of interrelated functional responsibilities, and the techniques of information handling are often definitely subsidiary considerations. To put the point partially into the language of mathematical experimentation, functional organization and physical considerations are normally the independent variables whenever change occurs, while data processing procedures and techniques are dependent variables, left to be developed as well as possible within the often severe boundary constraints of the "prime" factors.

The significance of all this lies in the fact that a feasibility study group often can, and certainly should, step beyond the customary bounds when synthesizing a new system that will use new data handling equipment. When the analysis of current ways and means has been completed, the study group should adopt the outlook of the systems engineer, in the sense that the concept embodied in this term has gained meaning and respect in the field of military weapons technology. The new system must be developed from the point of view of the job to be accomplished and the best means of accomplishing it, not in terms of the trappings and trivia of current organizational, physical or other artificial restrictions. The new system should be designed and developed <u>as</u> a system, and not be merely a piecing together of component procedures which should do the job. This approach need not be revolutionary, nor subject to criticism as a "blue sky" view. It will simply aid in the development, through the feasibility study, of plans for sound use of data processing equipment available or to come, and will avoid setting the sights no higher than a simple exchange of data processing tools.

Finally, before leaving discussion of the application analysis phase of the feasibility study, one other point, related to the foregoing observations regarding systems engineering, is very pertinent. The results of a feasibility study will be more easily made meaningful to the management people who must eventually decide whether to proceed with an installation program, and the work that follows an affirmative decision on the results of such a study, will be made easier to accomplish, if a strong theoretical foundation for the data processing program is developed along with the study. A stated set of conceptual fundamentals, with which the objectives, steps and techniques of the recommended data processing program are demonstrably consistent, can do a great deal to clear the way for actual transition to the successful, rewarding use of electronic equipment.

Such a theoretical foundation should be stated in the terms of the

organization to which it applies, and it should be specifically related to the long-term plans and prospects of that organization. It need not be overly complex, nor obscure in its treatment of the subject, yet it should provide the uninitiated with a sensible rationale of the "mode of thinking", so to speak, about data processing within the organization involved. For example, the relatively few, fundamental classes of transactions affecting an organization may be isolated and described. With this done, the specific facets of the data processing program which are related to each transaction can then be represented in a systematic way, and principles which are to apply throughout can be made clear in themselves, as well as obviously consistent with general objectives such as improvement of the scope and precision of managerial control of the enterprise. Furthermore, once the conceptual framework has been built, it can be a base line against which the relative soundness of short term plans and projects can be scaled. It should, in fact, be a statement of the goal, which, while beyond complete attainment, can be very helpful as an arbiter of means.

Equipment Manufacturers

When a system plan has been developed and a sequence of potential applications defined, the feasibility study can enter a phase wherein the people who have conducted the study become critics and judges. The study should have yielded sufficient system design information and application data at this point to permit electronic data processing equipment manufacturers to prepare proposals stating essentially how their equipment will perform under selected conditions.

These proposals can and do take many forms, all the way from advising that a project be dropped, to proposing the use of some equipment that is still largely in an engineer's head. Usually estimates of equipment processing times are included for one or more defined applications, and proposals regarding equipment cost, operational staffs, equipment delivery, site requirements and maintenance needs are made. In relation to this work, the feasibility study group has two simple functions; to supply the manufacturers with the application information needed to make the proposal, and to evaluate the results.

But the end-purpose of the feasibility study, that is, facilitating a major decision to proceed or to wait, should be kept firmly in mind during this stage of proposal preparation, for much can be learned by the study group regarding the practical difficulties of programming and operating particular data processing systems. If at all possible, all proposals should cover the same application so that comparisons of the end results are against the same base. The proposals submitted should be studied, questioned and discussed with the respective manufacturers in a thorough manner.

Aside from the obvious desirability of obtaining proposals from more than one manufacturer, there seem to be no specific criteria to guide a feasibility study group in the prosecution of this phase of their work. What should satisfy their needs with respect to the degree of proposal detail, the amount of commitment to estimates on the part of manufacturers, the amount of inter-manufacturer critique of proposals permitted or sought, and so on, are matters best left to judgment in the context of particular situations. About all that can be suggested is that the study group let their judgment be conditioned by the cautions embodied in the many familiar platitudes pertinent to the buyer-seller relationship.

Final Decision

The final phase of the feasibility study, evaluation and decision, usually involves both members of the study group and the managers to whom they were made responsible at the beginning of the study program. This stage, like the application study phase, may be very easy or very difficult to get through. Furthermore, it is here, more than anywhere else along the way, that the effects of proper or improper launching of the whole feasibility study will be felt. Since, as I have noted, a major, relatively long-term commitment of business resources may well be involved, a decision either way cannot be taken lightly.

If the feasibility study group has kept this final phase in mind during earlier stages, there should be no lack of information upon which to base a decision, and in this sense, the study will have fulfilled its purpose. Given a conceptual view of the data processing problems and potentials in a business, along with thorough, studied application and conversion plans, including scheduled and costed projections of equipment, personnel and facility requirements, and having these logically related to forecasts of savings and improvements to be garnered by proceeding, a sensible, reasoned decision can be made. If the decision is not to acquire electronic data processing equipment, the fruits of the feasibility study will be measured in terms of the assurance afforded the organization involved by its ability to adopt a conscious, supportable position regarding electronic equipment use and also in terms of the opportunities for more conventional operational improvements which will undoubtedly have been revealed by the feasibility study. If the decision is to proceed with conversion, the plans will have been laid and the bench marks of progress specified, so that the force of coordinated, reasoned effort throughout the organization can be directed to the attainment of thoroughly understood goals.

AMERICAN KNOW-WHY

Dwayne Orton
International Business Machines Corporation

When FORTUNE Magazine wrote up ECA in 1950, this significant statement appeared alongside Mr. Hoffman's picture: "When Paul Hoffman became head of ECA in 1948, his job was to use the strength of the American economy to rescue collapsing Europe's. In two years, this rescue job was done. Now Hoffman has a more delicate mission: to use ECA's dollars as an incentive to Europe's economic reform. Those dollars are backed by the skill of an American businessman and his faith in the rightness of his mission."

"Faith in the rightness of his mission." Are these strange words for reference to a business venture? Have we not been taught that faith is for the religious life? Faith in business in which production is limited to a safe volume, in which markets are protected by locking out the threat of competition, in which profits are assured by high mark-up on low volume, and in which the labor supply is immobile in a stratified society? Faith in an economy dominated by Old World orthodoxy?

Rightness - here is a term for philosophy and religion. These areas have no relation to the crass commercial world. But do they?

And what of "mission" - one worthy of faith and rightness? Was not the sole mission of business to make a profit for the owner-director?

Faith in the rightness of our mission in 1956 as in 1948 is the crying need of our hour. These words that are foreign to a static Old World economy are practical and promising words in a dynamic economy.

American economic and business missions have become a habit. Some of our friends across the seas think of us as prodigal sons returning home without the necessary repentance. No doubt many of us have gone abroad as arrogant, smug, almsgiving do-gooders. These are unfortunate exceptions to the spirit that has motivated the many missions of these difficult postwar years. Whatever has gone from America to other peoples has been a return-dividends if you please - on the investment of heritage, culture, philosophy, education, science, language, and religion which the older world bestowed upon us.

Since World War II, there have been two basic missions. One was to assist in the repair and stimulation of the economy of Europe. The devastation of the war - our war as well as Europe's - was essential to the survival of Western Civilization. There was no special virtue in our service. Repair and restoration of the economy of the old world was as much a part of the war as was the fighting. We were in it for our own salvation and no special accolade is due us for this "operation salvage."

The second mission is called by many names. Point Four was first used. Technical assistance and now technical cooperation are the designations. Conceived and developed in America, it has become a veritable network of mutual assistance criss-crossing the globe as 70 nations supply help to augment self help in 91

countries. Most of the donating countries themselves are recipients under the technical cooperation and assistance program.

These programs are a world-wide pool of engineering, education, medical, industrial, scientific, economic, and religious aid for reducing misery and lifting the level of life. Technical cooperation specialists of the United States International Cooperation Administration, technical assistance experts of the United Nations and its ten specialized agencies, the sixteen nation Colombo Plan for South and Southeast Asia, many world-wide private industries and institutions of education are the instruments of their vast sharing of skill and knowledge. The productivity KNOW-HOW programs of this period are a forerunner of the free and helpful use of knowledge which will characterize a world at peace.

Although the KNOW-HOW missions of the world will go on, although our opponents in the Cold War have adopted it, we now approach another phase which has thrust upon America a new mission - the mission of KNOW-WHY.

For five years, it was my privilege to preside over the committee of the Council for International Progress in Management which has sent thirty-four top management teams of American executives to Europe, Latin-America, and the Near East and Japan. They have gone at the invitation of foreign government and quasi-government agencies to share American KNOW-HOW with European industrialists of equivalently high status. The inviting governments share the costs with ICA. The work is part of the "productivity" program of ICA. Its primary purpose is to deal with KNOW-HOW but in many different ways this movement has revealed that the greatest need from America is not KNOW-HOW, important and critical as that is. The crying need of the times is to share the KNOW-WHY of the American economy.

KNOW-WHY deals with the underlying basis of the American economy, with the fundamental motivations underlying our phenomenal development of wealth. It is one thing to discuss the industrial engineering methodology of mass production; it is quite another thing to reveal the sub-surface currents of social motivations which gave power to expanding movement of our economy. This is the field of KNOW-WHY.

Stated formally it is: Business is a social as well as an economic institution with principles, goals, and practices which are moral and social as well as economic. Let us work it out together.

I

Faith in Products: American KNOW-WHY is founded in the faith that the economic process of exchanging products and services is a means to better human relations.

Let me hasten to point out that I am not here referring to the improvement in ways of living that are primary purposes of modern products. The vacuum cleaner relieves the housewife from drudgery and adds to the level of living. That is fine. However, we are here concerned with the great network of communication which the distribution of goods throughout the world community has

established. Products in this network are the carriers of ideas, ideals, and practices of human relations - for better understanding or for disharmony. In the associations of commercial intercourse, we either learn to link arms in mutual helpfulness or we clash elbows in painful conflict. Trade is not primarily the exchange of goods and services; it is a process of human relations in which goods are the means to the end.

It has been this way from early recorded history. Trade has been the great civilizer or divider.

Nowhere have I seen this expressed so well as in an advertisement of the John Hancock Life Insurance Company which shows the frontier huckster-salesman of America. He stands by his wagon with its stores of household goods - brooms, pots, pans, dress goods, etc. - as he talks to the housewife. The caption reads, "He Sold Progress from Door to Door."

> "He came on muleback, dodging Indians as he went with a pack full of better living and a tongue full of charms.
>
> For he was the great American salesman, and no man ever had a better thing to sell.
>
> He came by rickety wagon, one jump behind the pioneers. Carrying axes for the farmer, and fancy dress goods for his wife, and encyclopedias for the farmer's ambitious boy.
>
> For he was the great practical democrat spreader of good things among more and more people.
>
> He came by upper berth and dusty black coupe, selling tractors and radios, iceboxes and movies, health and leisure, ambition and fulfillment.
>
> For he was America's emissary of abundance, Mr. High-Standard-of-Living in person.
>
> He rang a billion doorbells and enriched a billion lives. Without him there would be no American ships at sea. No busy factories, no sixty million jobs.
>
> For the great American salesman is the great American civilizer and everywhere he goes he leaves people better off."

The only difference between the frontier salesman and the world frontier is that the latter is larger and that there is a determined and ruthless competitor who has stated and acts on the policy of controlling the world.

There are a billion people - half the population of the world - among whom the philosophy of KNOW-WHY may work like a beneficent virus to lift the standard of life and to establish peace. Within these people, there is a ferment of new aspiration and hope for Twentieth Century life free from poverty, igno-

rance, and disease. They are looking to the KNOW-HOW of the world for fulfillment. We can help them realize their hopes as free men if we undergird our wealth and skills with a missionary spirit of sharing the intangibles of good human relations with the products. This is the meaning of the late Thomas J. Watson's famous slogan: "World Peace Through World Trade."

The modern trader is a modern missionary "with faith in the rightness of his mission."

II

Faith in Purposes: American KNOW-WHY is rooted in the faith that the motive of service to people is good business as well as good human relations.

Service has become a watchword of our enterprise. It finds its expression in such slogans as "He profits most who serves best." As a member of the organization using that slogan, I have often wanted to change it to read: "He who serves best profits most." One of the best by-products of this feeling is to take service out of the realm of alms-giving and place it on a firm, practical platform of profitable practice.

In its great article on the Domestic Economy several years ago, FORTUNE editors wrote: "The many corporate managers who so solemnly mouth service are not fooling anyone, not even themselves. They are struggling, if only subconsciously, to find a new social principle by which their power may be made legitimate."

The orthodox dimensions of business are to a) produce goods and services, b) utilize and reward capital investment, and c) provide and reward labor. To these we now add a fourth dimension: So to practice the economic dimensions as to make the whole enterprise serve the general welfare.

Boiled down to its simplest terms in the complex of KNOW-WHY, this means "Production for People." Mr. Henry Ford put it well when he said he wanted to have a car in every family. High production and low profit margin in a free and competitive market is the formula. KNOW-HOW increases the productivity of the man in order that he may produce more wealth and earn more money which, in turn, enables him to buy more and sustain the larger production. Expanding sales in an expanding economy requires expanding men.

Comparisons are often odious and always fall short of the whole truth, but an incident in a southern European city illustrates our point in reverse. One of our CIPM seminar teams had been discussing the KNOW-HOW of scientific management with a group of industrialists when one of them said: "Why should I do everything differently in my factory when I have all the money I need now?" It was a sharp answer but a pertinent one. Capital and management should share in the increased fruits of productivity but the great consuming public who do the work and who buy the products are the key factor in the capitalistic economy.

Capitalism's answer to the communist dogma of internal disintegration of the free enterprise system is right here. Production for all the people unfettered by limited quantities on high margins of profit and tightly protected

markets. Production for all the people in an expanding economy is the central fact of American KNOW-WHY.

III

Faith in People: American KNOW-WHY is sustained by the faith that human values are supreme and that they will win out in the struggle against materialism.

The fundamental issue in the struggle across the "curtains" of this world is the supremacy of human personality - it is between a system which holds that the state is the final entity - that man is made for the state - and our belief that man is to be served - that the state is made for man.

This was nowhere in modern experience more sharply illustrated than in President Eisenhower's book, "Crusade in Europe." Marshal Zhukov accompanied General Eisenhower on his return flight from the Soviet Union to Berlin. The two commanders exchanged views on military procedures:

> "Highly illuminating to me was Marshal Zhukov's description of the Russian method of attacking through mine fields. Marshal Zhukov gave me a matter-of-fact statement of his practice, which was,roughly, 'There are two kinds of mines; one is the personnel mine and the other is the vehicular mine. When we come to a mine field our infantry attacks exactly as if it were not there. The losses we get from personnel mines we consider only equal to those we would have gotten from machine guns and artillery if the Germans had chosen to defend that particular area with strong bodies of troops instead of with mine fields. The attacking infantry does not set off the vehicular mines, so after they have penetrated to the far side of the field they form a bridgehead, after which the engineers come up and dig out channels through which our vehicles can go.'
>
> "I had a vivid picture of what would happen to any American or British commander if he pursued such tactics. Americans assess the cost of war in terms of human lives, the Russians in the over-all drain on the nation. The Russians clearly understood the value of morale, but for its development and maintenance they apparently depended upon over-all success and upon patriotism, possibly fanaticism.
>
> "As far as I could see, Zhukov had given little concern to methods that we considered vitally important to the maintenance of morale among American troops: Systematic rotation of units, facilities for recreation, short leaves and furloughs, and above all, the development of techniques to avoid exposure of men to unnecessary battlefield risks, all of which, although common practices in our Army, seemed to be largely unknown in his.

"The basic differences between American and Russian attitudes in the handling of men were illustrated on another occasion. While talking to a Russian General I mentioned the difficult problem that was imposed upon us at various periods of the war by the need to care for so many German prisoners. I remarked that they were fed the same rations as were our own soldiers. In the greatest astonishment he asked, 'Why did you do that?' I said, 'Well, in the first place my country was required to do so by the terms of the Geneva Convention. In the second place the Germans had some thousands of American and British prisoners and I did not want to give Hitler the excuse or justification for treating our prisoners more harshly than he was already doing! Again the Russian seemed astounded at my attitude and he said, 'But what did you care about men the Germans had captured? They had surrendered and could not fight any more.'"

KNOW-HOW meets this issue on its material terms. The great network of mutual assistance provides for better living conditions. Scientific management, industrial engineering, and personnel administration will provide the techniques of expanding production. KNOW-WHY provides the spiritual insight and social drive to sustain the system.

KNOW-WHY is a new industrial revolution. Saul Silverstein, President of Rogers Corporation has put it clearly: "The United States is indebted to Europe for the benefits derived from the Industrial Revolution; now it is apparent that Europe and the rest of the free world must soon be indebted to the United States for the benefits of the Marketing Revolution which is in progress here."

The Industrial Revolution started in England and Europe because the development of the people and the economy was ripe for it there. The Marketing Revolution got its start in the United States and Canada because, in God's own time, the economy of liberal capitalism and democracy had matured here to sire it.

Professor William E. Rappard, noted Swiss economist in a recent book on the economic system of the United States - a work widely acclaimed in Europe as an objective study of us - comments, "The United States is the world's richest country because it is the world's greatest producer of wealth - not so much because the United States is generously endowed with natural resources as by the fact that they have succeeded in making better use of human work than their competitors abroad."

This KNOW-WHY revolution is not to be spread by preachment or by arrogance and disdain of other races and peoples. It will become a part of the world's economy when those who have it in America and elsewhere throughout the world combine humility with faith in the rightness of the mission. This is expressed in Clarence Francis' "Businessman's Creed":

"I will speak out in behalf of my business and the system it represents.

"I believe that business is a public trust, that it must offer a message of courage and hope to all people, and that it can help an economically strong America to lead other nations to lasting prosperity, freedom, and peace.

"I will work not only for the advancement of myself, my family, and my country, but for liberty and democracy for America and the world now and in the years to come."

Now will the revolution be successful by the spread of KNOW-HOW technics only? If we may take liberties with St. Paul to say, "If I speak with KNOW-HOW of science, engineering, medicine, agriculture, and education and have not the spiritual concern of KNOW-WHY, I am as sounding brass and a clanging symbol."

Erwin D. Canham in his great essay, "The Authentic Revolution," points out that "the struggle for the salvation of free society in our time will be lost unless we in the West - and particularly we in the United States - awaken to and project the fact that we are the great revolutionaries in world history, and that our revolution is basically a spiritual one which we have already proved in action."

Editor Canham quotes Dr. Charles Malik, Minister of Lebanon to the United States, to present a voice from the East:

"To the superficial observer who is unable to penetrate to the core of love and truth which is still at the heart of the West, there is little to choose between the soulless materialism of the West and the militant materialism of the East.

"If your only export in these realms is the silent example of flourishing political institutions and happy human relations, you cannot lead. If your only export is a distant reputation for wealth and prosperity and order, you cannot lead. Nor can you really lead if you send forth to others only expert advice and technical assistance. To be able to lead and save yourself and others, you must, above everything else, address your mind and soul. Your tradition, rooted in the glorious Graeco-Roman-Hebrew-Christian-Western-European humane outlook, supplies you with all the necessary presuppositions for leadership. All you have to do is be the deepest you already are."

But this revolution is not America's responsibility only. It is a charge upon freedom-loving men everywhere. Arnold Toynbee has pointed out that the "Twentieth Century will be remembered as the first age in history in which people have thought it practical to make the benefits of civilization available to all mankind."

The revolution is contagious. Ramon Magsaysay conquered the Huks of Luzon by providing land, education, and opportunity in a capitalistic system. Observers from all over Southeast Asia and the sub-continent have beat a path to the Philippines to observe this modern mission in good human relations. This is Asia for Asians and production for people.

The KNOW-WHY revolution, to use a statement from the conclusions of the International Development Advisory Board "offers these men leadership in building rather than in destroying, a life's work of self-fulfillment rather than of frustration. It directs their idealism, their energies and patriotism towards freedom rather than enslavement, toward justice and equality based on creating new wealth rather than misery."

Faith in Products - Faith in Purposes - Faith in People - Faith in the rightness of the new revolution - our mission.

A PROGRESS REPORT ON WORK SIMPLIFICATION

Herbert F. Goodwin
Massachusetts Institute of Technology

Today we are living in an age of progress and improvement unparalleled in all history. What is more, the rate of improvement is rapidly accelerating. We are on the threshold of an era of science and engineering which can revolutionize the standard of living of mankind beyond our wildest dreams. Yet utter chaos may well be the net result if we fail to consider the need for the understanding and enthusiastic assistance of everyone involved.

There are those among us as well as afar who would see us fail. As an incurable optimist imbued with an overwhelming faith in the intelligence of the American people I am confident we shall not fail.

The responsibility for implementing the improvements which must come lies with Management. As a representative of that function in management the Industrial Engineer will play an all important role.

As an Industrial Engineer I have been asked to present to you a progress report on Work Simplification. I do so for the purpose of establishing where we now are so that we may look ahead from there much the same as a navigator pauses en route to shoot the sun or the stars.

THE TERM WORK SIMPLIFICATION

Professor Erwin H. Schell of Massachusetts Institute of Technology coined the term Work Simplification to portray the approach to improvement developed by Allan H. Mogensen. Mogensen used the principles of motion study originally developed by the Gilbreths as the foundation for structuring a program in which every member of an organization might participate. This procedure he defined as "the organized use of common sense to find easier and better ways of doing work".

Over the last two decades Work Simplification has taken on a broader and deeper meaning through this shift of emphasis to the human relations involved in the improvement process; friendliness, understanding, and teamwork pervade the philosophy of Work Simplification.

New tools and techniques are being utilized together with more time-honored procedures which are being constantly improved and refined. All are tending to become group oriented.

The effective application and use of Work Simplification is currently receiving more attention. Efforts are being made to organize self-perpetuating and continuous programs of improvement within the enterprise.

Communication channels are being cleared for the reporting of progress, the recognition of participants and the introduction of new material as it develops.

The broad objectives of Work Simplification are:

1. Increased rate of improvement as a result of the coordinated efforts of everyone in the organization to achieve this goal.

2. An accelerated personal development of the people who participate in the program.

THE WORK SIMPLIFICATION PHILOSOPHY

The basic fundamentals of the Work Simplification Philosophy can best be exemplified by a simple experiment known as the "Peg Board Demonstration". This experiment was first used to illustrate this Work Simplification Philosophy by Harold Dunlap of H. P. Hood & Sons, Inc. of Boston.

If one member of a group is requested to assemble some pegs into a number of holes in a board a spontaneous attempt will be made by the rest to improve the method of doing so. Usually the time for the cycle is more than cut in half.

The ensuing discussion in response to a question of what happened can readily be summarized in four simple statements.

1. It's fun to participate in group activity.

2. People naturally like and try to improve when given the opportunity.

3. It's not what we do but the way we do it.

4. It's not what we say but the way we say it.

Many people in groups such as these express an overwhelming desire for satisfaction and enjoyment in their daily work. Work Simplification seeks to find and apply improvements in an atmosphere of understanding and teamwork which may satisfy this desire.

Since we were children we have constantly set up goals and standards whereby we can measure our personal progress and then try to exceed them. Work Simplification seeks to utilize the natural desire of people to improve by providing an opportunity for each to do so within the framework of their ability.

It is obvious to most of us that better work methods should result in increased productivity. It is less obvious that the method of arriving at these improvements and the methods of management and leadership to attain their effective use are equally if not more important. Work Simplification seeks to develop an organization which understands and believes that in the method of doing anything lies the secret of progress.

We are all aware of the difficulties of semantics and the ease with which we can be misunderstood or our actions misinterpreted. Work Simplification seeks to develop an attitude of mutual respect and confidence through unrestricted channels of communication acceptable to and utilized by the entire organization.

Fear and mistrust are the universal inhibitors. Personal acceptance by ones friends or fellow workers is an important factor. Work Simplification seeks to replace these fears with understanding, mutual confidence, and teamwork. The natural desire to improve becomes available for effective use when people begin to realize that do so is in their own best interest.

WHAT'S IN IT FOR ME?

Positive motives for improvement are emphasized in the Work Simplification Philosophy. The long range goal of a higher standard of living for everyone in a free economy is readily accepted by most people today. The current outlook for the individual is dominated more by his personal experience and attitude toward the situations which influence his day-to-day living.

The responsibility for maximizing a feeling of security at all levels in return for a job well done rests with top management. A response of wariness and doubt is readily understandable if there is no apparent concern in this regard. Actual conduct is the hallmark of policy rather than the written word.

Pressures beyond control, such as the action of a neighboring company, news interpretations by columnists, and politicians, have a significant bearing on specific situations. Wise leadership avails itself of every opportunity to publicize their own performance.

Above everything else we are recognizing the need for the individual to perceive opportunity and personal recognition. The higher we go within the organization, the more these two appear dominant. At the lower levels security shares in importance.

Whatever his level of activity, the Work Simplification Philosophy embraces the concept that everyone accomplishes their own personal objectives because of or through the activities of other people. It is, therefore, to anyone's personal interest to develop an acute sense of interest and understanding of human relations. The common sense of this truth is very readily developed if the opportunity to do so is made available.

RESISTANCE TO CHANGE

It is a time honored truism that people resist change. It is also quite easy to get a universal agreement on this point, particularly after citing such famous examples as iron

ships, steamboats, automobiles, and airplanes, all of which initially were condemned as impractical. Even today we scoff at the possibility of interplanetary travel as quite in the realm of fancy.

The Work Simplification Philosophy recognizes this phenomena in human behavior as a major obstacle and attempts to create the desire to better understand why it exists. A careful self-analysis is an effective prelude to a realization of why others appear to resist change. What really are the frames of reference and biases which dominate our thinking and that of others to produce this effect? Why do they exist?

If we pursue in depth some of the ideas and notions which arise as a result of this questioning it becomes quite evident that few changes are resisted and those that are have well founded bases for the resistance in the minds of the people affected.

A colleague of mine, Professor Leo B. Moore of M.I.T., makes the following statement in his article "Too Much Management, Too Little Change" published recently by the Harvard Business Review:

> "Contrary to the common management assumption, it can be demonstrated that people really like to change and do not mind criticism if they make the changes and criticisms themselves. Subordinates resist the new ideas of managers and the line men resist the ideas of staff experts because of the positions they are manuvered into."

The atmosphere of Work Simplification is one of understanding and friendliness through participation. New channels of communication are opened to make available information which leads to understanding and confidence. Resistance to change is minimized through a new attitude of teamwork and cooperation.

RESENTMENT OF CRITICISM

The implication of any proposed improvement as a result of Work Simplification is criticism of the existing method, criticism of a method is usually accepted as directed at a person by the one who is doing the operation or who was originally responsible for setting it up. This resentment is ingrained in people with a high degree of pride in their work. The Work Simplification Philosophy which embodies participation to the fullest extent possible minimizes the ill effects of criticism. The very fact that there is a mutual effort on the part of a group to improve things as they now are or insure the installation of new procedures and methods with fewer built in headwinds is part of the answer. People working in such teams often criticize themselves with such vehemence that one might think they were proud of their stupidity. Resentment of criticism permeates all levels in an organization as does the willingness to ignore its implica-

tions in response to an avarice of praise.

Numerous symbols are being used as devices to dramatize these points and to act as a face saver for those prone to react too quickly to implied criticism. The red and green of the traffic light in signs or a desk ornament would be one such symbol. Reference to its presence is in effect a license to expect immunity from the implication of criticism. Understanding, confidence and mutual respect are still the biggest factors in overcoming it.

TOOLS AND TECHNIQUES

The tools and techniques of Work Simplification are the tools and the techniques of the Industrial Engineer. They are all the tools of research used by science, engineering and management for the purpose of improving methods, procedures and processes. They are a grand composite of the techniques of psychology and leadership oriented toward a cooperative effort at all levels to implement improvement as such.

Some of us may feel that this goes too far. For example, the techniques of operations research and statistical quality control are viewed by many as professional fields by themselves and I agree. I have heard operations research described as "the work of people using advanced mathematical techniques for solving industrial and business problems". This is a broad discipline and certainly requires the knowledge of experts. But the very fact that it does, implies the need for teamwork to feed appropriate information with regard to the specific situation into the mill for analysis. The problems of implementation are the same - that of developing confidence, understanding, and respect for the procedure itself on the part of executives, managers, and supervisors alike and to program its application effectively so that time invested is time well spent.

And so it goes with other special techniques such as those of production and inventory control, work measurement, standardization, and new product development. All must win the respect and confidence of the entire organization if useful implementation of their efforts is to be the result.

An effective program of Work Simplification can therefore build the foundation for improvement on a cooperative basis throughout the enterprise. All of the tools and techniques being effectively used on a coordinated basis each to the extent of his ability.

Work Simplification is much more than foreman training, although it may have begun in that area. It is much more than training alone at all levels. It, indeed, is more than programming problem solving and finding better ways. It, in essence, is the vehicle for programming improvement throughout the enterprise each to the extent of his ability.

An eminent surgeon recently commented while working on the peg board during an appreciation session, "What the

dickens am I doing putting pegs in a board when I could be upstairs grinding the valves on somebody's heart?" A little later he answered his own question when he said, "I can see where my time can be more effectively spent performing the 'do' of my profession if the rest of the organization is enthusiastically and effectively performing their job as part of the team".

The lot of the Industrial Engineer will become much better in all respects when everyone from the President to the sweeper considers himself a junior industrial engineer and constantly looks to the expert for help and advice.

PROGRAMMING IMPROVEMENT

A Work Simplification program in order to be effective must begin with the top man in the organization. This is the man we might well call the "Yes or No Man". He is the man who can say "yes" or "no" and mean it. He along with his top executive policy-making group must have a thorough appreciation of the philosophy of approach and the objectives and long range aspects. He must also be aware of the part he plays in the team.

A preliminary appreciation on the part of all levels of management is essential to exemplify the open lines of communication and the forthrightness which will pervade the program. No less important is the appreciation of the implications of improvement as they affect the entire work force.

This may be considered phase one of the program which we may call the appreciation phase. In essence it is a preview of the activity as it will affect them. It is usually accomplished with a series of meetings which demonstrate the friendly participation approach.

EDUCATIONAL ACTIVITY

The education phase is that part of the program which many of us call training. Here we have a matter of semantics again. Most of us prefer the term education in its broader sense as an experience of learning within which to grow and think independently, whereas training seems to imply the teaching and practice of an established discipline. It is our fervent hope that as we seek to improve in all areas of activity within the organization, innovation within the improvement process itself as well as in teaching it will not be overlooked.

Through an organized series of educational conferences which range from all-day sessions to a series of half-hour meetings the philosophy, the tools and techniques, and the procedure for applying improvement within the specific company are reviewed by all levels of the organization. The philosophy previously discussed here is developed by demonstration and experimentation through participation. The tools and techniques developed during the early stages are the Process Chart, the Flow Diagram, and the principles of motion

economy along with the fundamental problem solving procedure to implement their effective use.

Here is the compounding of the creativity of the group all the way from brainstorming improvements in the layout of a work space to delineating alternative designs of a major piece of automatic equipment.

The need for separating the judicial from the creative becomes an appropriate development with economic evaluation of alternatives the major concern in the former.

The human problems of acceptance become the final step of consideration as they experiment with improvement. These considerations both up and down the line, as the case may be, give credence to the need for understanding and cooperation.

An appropriate discussion for transition from the educational phase to the application phase is that of appropriate selection of projects worthy of the small amount of time available. The proper types of activity for various levels in this regard is also an important consideration.

THE APPLICATION PHASE

The application phase of a Work Simplification program is the organized and continuous use of these common sense tools of improvement, by the entire organization commensurate with their ability and the amount of time appropriately invested. Backlogs of projects listed during the educational phase are constantly reviewed for proper assignment of priority within each area of activity. As this procedure becomes routine the people involved begin to accept improvement as routine.

The man in charge of the activity begins to recognize his responsibility for seeing that improvement is continuous and that the highest level of brains available and appropriate is brought to bear on his problems.

THE COMPLETE CIRCUIT

The programming circuit is completed through the media of regular reviews of progress by top management. This means review of high level major improvements as well as those further down the line.

Motion-picture films are an effective means of reporting progress on specific projects. During the past decade the traditional before and after film has given way to the documentary, in which the story of the people involved in the improvement take the lead in importance.

The completion of this circuit is the major factor in stimulating new projects, recognizing those who have participated in completed improvements, and adding grist to the mill with fresh material and new techniques with which to experiment.

This is the open line of communication which makes available the improvement activity throughout the enterprise in such a way as to invite help and assistance from those in a position to do so.

COORDINATION OF THE PROGRAM

This basic program is usually coordinated by a full time Industrial Engineer in the average plant. His emphasis, however, becomes one of programming and leadership through catalyzing others. This in no way detracts from the other industrial activities in the company, rather it enhances them. For more detailed information on this general philosophy of programming may I refer you to my own article on that subject in the January 1957 issue of Advanced Management. For more detailed statistics on how the educational phase is being set up all over the country, see the "Work Simplification Survey" conducted by the Factory Management Division of Sears, Roebuck and Company a couple of years ago. Mr. F. W. Simerson, who conducted that survey, will be happy to send you a copy of it in answer to your request.

A LOOK AHEAD

A progress report on an improvement procedure such as Work Simplification would hardly be complete without glancing toward the major areas of innovation we may expect in the future. The following are simply the considered opinions of the writer.

Top management in the future will become more conscious of the need for balance in the improvement process. There will be more recognition that others beside the professional men have thoughts that are worthy of consideration and if given the opportunity, they will enthusiastically contribute them and will improve their ability to do so. The responsibility for improvement will gradually become accepted at each level as an activity commensurate with the ability at that level. The improvement process will thus tend to become appropriately balanced.

There will be a general upgrading of the professional man and the expert will take an appropriate position high in the esteem of everyone. His advice will be sought in order that the most experienced and educated brains may be brought to bear on the problem. Thus, a better decision can be made by the people responsible for the activity. In this atmosphere he will find himself working on increasingly higher level problems with more time to spend on them. Little or none of his time need be wasted fussing with routine detail. Thus his productivity will be enhanced and his position take on greater importance.

A new kind of teamwork will spring up. Recognition and understanding breeds confidence and respect and they, in turn, breed enthusiasm and cooperation. The tendency to view one's activities as a part of the whole rather than omnipotent will become increasingly apparent. This sort of teamwork may be-

come powerful enough to transcend traditions of long standing. Enlightened workers who participate in improvement to the extent of their ability and have a new faith in their leaders will accelerate their acceptance of their rightful place as an integral part of management. The capital values managed by each worker will become increasingly great as the trend toward more complex and costly facilities continues. His ability to assist will likewise be enhanced as the technical requirements of the job enlarge and as the technical educational processes are carried further back into secondary schools. More and better education through our schools and through such new media as television will still further improve the mental capacity at all levels. More people will be doing their own thinking than ever before.

Finally, a new concept of improvement will emerge as a function of management based on the philosophies reviewed here. As my colleague Professor Moore states in his article on the "Management Laboratory", Tech Engineering News (M.I.T.) May 1956:

> "The avowed functions of managers - planning, organizing, staffing, directing, and controlling - do not include 'improving', because for some reason, this is believed to be inherent in the five functions. If on no other basis than that managers consistently have difficulty in effecting day-to-day improvement, the Management Laboratory (at M.I.T.) has added to the list the sixth function - improving."

This function will develop through Work Simplification as a vehicle.

THE PLACE WE BEGIN

As I ponder the situations in which many of us may find ourselves with respect to effectively utilizing Work Simplification in our own plants and offices, I am reminded of the man who became lost while driving alone over the Appalachians on his way to Cincinnati. The reply to his request for directions from an obvious native went like this:

"Go right up the road the way you're headed, turn right at the fork and.....No, I wouldn't go that way - the road's impassable. Take a left turn at the fork and left again at the red schoolhouse. When you cross the bridge.....No, the bridge is washed out. I tell you what. Go back the way you came, turn down into the wagon road at the yellow barn and when you pass the still.....No, you couldn't get by there. You know stranger, if I were going to Cincinnati, I wouldn't start from here."

Many of us do not relish the situation in which we find ourselves. We may seem to have insurmountable barriers in our way. We may have impatience to progress much more rapidly than we are in the direction I have outlined. This, however, is where we are, ladies and gentlemen, and from here we shall proceed.

Don F. Copell, Vice President of Wagner Baking Corporation has said, "The smart man in this world is the one who can take things as they are and make them work out to his advantage." Your success will most certainly depend on the understanding and enthusiastic assistance of all of the people involved. May you have the best of good luck in your efforts.

THE INDUSTRIAL ENGINEER AND QUALITY CONTROL

J. M. Juran
Consulting Management Engineer

Summary

A major industrial phenomenon of the 20th Century has been the rise of the mass production of precision goods. Among the problems posed by this phenomenon has been the need for new tools for establishing and achieving quality standards.

Development of these new tools has proceeded unevenly. Some tools, notably statistical methods, are well developed. Other vital tools lag behind. This unbalance has contributed to inadequacies in solution of the new quality problems.

In proportion to his potentialities, the Industrial Engineer has to date made but little contribution to solving these problems. However, the nature of the solutions needed suggests that the Industrial Engineer should expand greatly his role in Quality Control. This expanded role would properly include activity in the following areas:

(1) Clarification of quality control policy.
(2) Development of economic principles for balancing the cost of quality with the value of quality.
(3) Development of optimum organization forms for handling the quality function.
(4) Expansion of the concept of quality planning to include the entire progression of events from specification to usage.
(5) Development of units of measure and of standards of performance for the quality function.
(6) Development of means for measuring quality performance against goals.
(7) Definition of the concept of quality-mindedness, and development of means for attaining quality-mindedness.

The explosive growth of mass production of precision goods suggests that nothing short of recognizing Quality Control as a major Industrial Engineering problem will suffice for adequate solution.

"Hate Paper-work Week"

A NEW APPROACH TO RECORDS MANAGEMENT

Arthur Barcan
Records Management Institute

This may come as a shock. Bound by gentlemen's agreements among various staff groups, there is as yet no finger pointing at the obvious:

When will it give up?

Why are there more labor-saving devices -- and yet, more clerical employees than ever before?

Why are there more cost reduction, work simplification and general "efficiency" programs -- and yet, clerical costs are higher than ever in most organization budgets?

This, at a time when the number of industrial engineers and procedures analysts are likewise on the increase!

Within the restricted confines of the National AIIE Conference, it seems appropriate enough to analyze in private what is bound to become a public scandal.

Scientific Records Management: Standards

When we first began to release the initial standards that formed the base for Scientific Records Management, we felt sure that the "rising tide of paperwork" would begin to ebb. After all, we could now tell business management that:

1. 65 cents out of every dollar spent for paperwork was wasted.
2. Each company was creating or processing at least 2,000 pieces of paper for each employee on their payroll every year.
3. At least 40% of all records could safely be destroyed as obsolete.
4. Another 25% could be transferred to low-cost storage.
5. These standards are equally applicable to government and industry -- and only a small portion of total records accumulations can be placed at the door of legal requirements.

This interested a number of companies and we started to make a dent in the volume of records being created and maintained -- but nothing changed the over-all picture or paperwork production. Well, we thought -- maybe our presentation is a bit too theoretical. We will translate these abstract standards into tangible returns. Thus, the Records Management Institute staff was able to highlight this picture for the average manufacturing concern with, let us say, 100 employees. It should:

1. Have no more than the equivalent of 62 file drawers of records in the office and storage.
2. Retain only 29 of these in the office.
3. Store the less active records at a total cost of $27.20 a year.
4. Utilize 33 square feet of space in the office and 6 to 7

square feet of space in storage.

5. Limit the vital company records to less than one file drawer.

6. Protect them by new techniques at a cost of one-half cent per document.

Compare this with what the average business with 100 employees still does:

1. Has over 103 file drawers in office and storage -- a surplus of 40 per cent that highlights creating, filing and maintaining 131,000 pieces of paper unnecessarily.

2. Retains over 70 of these file drawers in the office -- more than double the standrad.

3. Stores the less active records at a total cost five times the standard.

4. Utilizes twice as much square footage as the office standard and five times the standard space for records storage.

5. Has no vital records protection at all or has gone overboard on moving them out of town or filming them so that the document protection cost rises three times the standard up to 1.5 cents per document.

No wonder the 65 per cent waste in paperwork costs is consistent, continuing and avoidable.

The fact is that companies are increasingly ready to admit that there is too much paperwork, that costs are too high, ad infinitum, ad nauseum and "ad to the number of memos on the subject". While professional standards may blast complacency and even evoke action, the standards per se are not automatic cures. The standards can only highlight whether there is a problem, what action may be taken, and "what is in it" for management. This area has become so highly developed that the analysis can be conducted and results presented within 1 to 2 days!

The Pitfalls of Paperwork Operations

If ignorance of scientific standards has prevented organizations from knowing just how healthy (or unhealthy) their records really were, then past "sacred cows" have mesmerized companies into believing that they are about as streamlined as they can be (or at least as streamlined as similar companies in their industry -- a case of mass hypnosis).

Let us examine just three of the "Seven Sacred Cows" that have managed to create this costly and undeserved complacency.[1]

1. Personnel and Paperwork. The first factory worker who would attempt to keep parts of the assembly he was creating as a sentimental reminder or "in case some one asked" would end up discussing it with plant security. On the other hand, our office worker automatically "participates" by retaining a copy of each of his products (letters, reports, etc.) and is equally adept at retaining copies of the products of others as well.

2. Quality and Paperwork. Quality in the factory is a complicated balance of tolerances and sample inspections: Q.C. constantly weighs

Among the things in the operations Department.

engineering pressures for accuracy against production pressures for shipments and against the "old man's pressure" for net profit. On the other hand, office administration blithely assumes its impossible standard of 100 per cent accuracy; regularly superimposes layers of formal and informal inspection to reduce errors; unquestioningly checks every bill, whether for $5 or $50,000, with the same painstaking detail.

3. Common Sense and Paperwork. This is the do-it-yourself technique based on the flippant assumption that common sense can tackle all problems, if bolstered by three articles on forms control, two sessions on filing and a dinner meeting on electronic data processing. Certainly, nothing has managed so well to keep paperwork operations in semi-efficiency and deserved disrepute. There are eight basic filing systems and hundreds of variations on the theme; there are dozens of "canned systems" for purchasing, invoices, etc; there are innumerable articles on records retention or vital records protection. Are all these areas for selection by intuition and common sense? Common sense is a valuable asset. Like a sense of humor, nobody admits to being without it. It is also invaluable in engineering, law and medicine, but we certainly do not attempt to practice these professions on the strength of common sense alone.

Scientific Records Management Techniques

Just to get the clichés out of our system, we all start out agreeing to favor motherhood, oppose sin, treat causes rather than effects, and admit that the above "sacred cows" exist in Joe's office or in other companies, but never in our own. The fact is that past anti-paperwork crusades made up in fervor alone what they lacked in direction or professional evaluation. Scores of people have been sent running around to ask, "Who, what, when, where, why and how" -- and then continue unprepared to interpret the answers they receive. Companies have embarked on cost reduction without knowing exactly how much clerical operations were actually costing.

The fact is that there are a number of excellent techniques to augment the scientific standards. There is not sufficient time to elaborate on these. However, one example may explain how we go from the general to the specific in an area like record keeping. In Company A with 10 employees in Purchasing Department, we find 54 file drawers of records in office and storage. Applying our standards, we know that at least 23 file drawers (or 46%) are excess. The pinpointing of exactly which records are vulnerable will be determined by the reference analysis as well as the legal requirements -- neither is a subjective matter of opinion or "common sense".

Experience indicates, for example, a different usage pattern in reference analysis for different types of records. Cancelled checks are a "sudden death" item, with immediate high usage until reconciliation and then a steep drop until audit time; records of terminated personnel do not show a steep drop until 6 weeks after departure; vouchers tend to hold up high until 6 months after payment. Again, while these are generalized patterns, the exact usage story for each record would be revealed under reference analysis.

There are equally valuable techniques for analysis of filing systems, correspondence, or of paperwork processing in specialized records systems (i.e., purchasing, sales, personnel, and production control).

Underlying these techniques, however, are two basic principles that require renewed appreciation and support for effective paperwork controls:

1. The Economic Tolerance Level.

Before manufacturing a product, we carefully consider which materials to use or which package to present in terms of total cost, estimated profits and customer acceptance. The same disciplined framework must hold true for the office. Why haggle over "make or buy" on a $2 spare part and then accept a $2.20 to $18.50 cost to process the purchase order? It is ceasing to be heretical to say, "What we need is a good eighty cent procedure. Let us see what we can buy for it and where it would be applicable". The clerical overhead cost runs at least $400 a year for every employee in the company. Until now, clerical processes have enjoyed deferment from the rough-and-tumble debates on break-even points by getting lost in the general overhead. Similarly, creation of records and reports has enjoyed the luxury of general streamlining and vague costing without the critical balance against value received.

Without techniques more professional than a "before and after chart", management has been able to ignore, if not justify, the laissez-faire policy in the office. Scientific Records Management provides us not with the usual two alternatives -- but with a series of alternatives, objectively developed in terms of service, cost and calculated risk. For the first time, management knows not only what it will do and save now, but, equally important, what remains to be done -- and saved.

2. The Exception Principle in Paperwork.

If last year's words were: I.D.P., this year's promises to be: exception principle. Any way you define it, it provides a firm base for our new area because we have already applied it effectively to differentiate between: routine and policy material; internal documents and outside correspondence; quantity purchase requisitions from material control and sundry requisitions from all over the company; orders fulfilled in one shipment as against the "stretch-out arrangement". In all these cases there is no question that both alternatives (plus further exceptions) exist. The job of effective analysis is to indicate what proportion of each operation is a job that is significantly different so that it can be handled as little, as simply and as quickly as possible. The sad truth is that in paperwork operations, with the possible exclusion of payroll procedures, the exception principle is not only an exception -- it is a downright outcast.

Conclusion

We started this discussion confronting a number of paradoxes. Let us face up to one more. In an era of rising sales, net profits are consistently lagging behind. This is uncomfortably related to rising costs generally and to clerical costs in particular, the largest signle maintenance budget item.

In these days, when each staff unit would like to report to the President, we have a subject that is already on the President's agenda. That minimum $400 clerical overhead cost per employee per year put it there. That desire for prompt, effective -- but minimum -- reports to management keeps it there.

Scientific Records Management now talks to top management in universal terms: the cost, quantity and quality standards for records and reports translated into tangible service and savings.

1. "Seven Sacred Cows of Clerical Routine -- Do We Need Them", Office Management, June and July, 1956.

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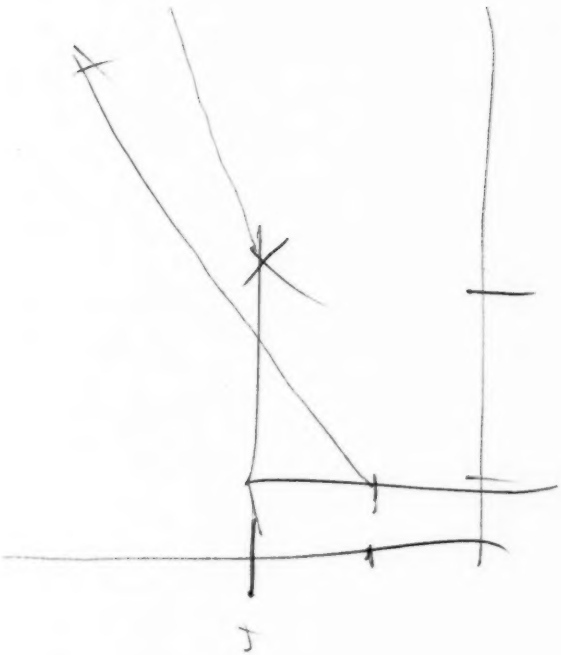

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